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NASA AUTHORIZATION FOR FISCAL YEAR 1985

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON

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NASA AUTHORIZATION FOR FISCAL YEAR 1985

TUESDAY, FEBRUARY 28, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:40 o'clock a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

Staff members assigned to these hearings: Peter Perkins, professional staff member; and Steven Flajser, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. I am pleased to chair these hearings of the Subcommittee on Science, Technology, and Space, as we consider the National Aeronautics and Space Administration's [NASA] fiscal year 1985 authorization. This Nation has become increasingly aware of the contributions which NASA has made and is making to our technological and scientific leadership. In the first 25 years since its creation, NASA has demonstrated excellence in all aspects of aeronautical and space activities. We look forward to a continued history of this excellence.

Equally important, NASA's achievements have been enormously important to our national will and aspirations. Earlier this month we marveled at our astronauts' first untethered space walk. We now look forward to our next shuttle mission in April when our astronauts will again make an untethered space walk, only this time to recover and to repair the solar maximum mission observatory.

NASA's accomplishments continue to give special meaning and purpose to our Nation's goals.

Today we will begin to examine the fiscal year 1985 authorization for NASA. The President's budget contains several salient features. Most noteworthy among them is his program to develop a manned space station. Developing man's ability to live and work for extended periods of time should open up new horizons and stimulate new technological advancements for the betterment of mankind. Further, this orbiting research laboratory and operations center should serve as the locus for a new partnership between the public and private sectors for space exploitation. We must now determine the most efficient and productive approach to achieve this permanent manned presence in space.

The new planetary mission to Mars is an important commitment to our desire to explore the mysteries of the unknown. Likewise,

the President's budget contains a new start for an upper atmosphere research satellite, a satellite that will provide our most comprehensive evaluation to date of the dynamic processes of the earth's stratosphere.

There are still other issues that must be addressed. Our Nation's present and future launch capabilities warrant close inspection. In the past, this committee has felt that a fifth orbiter was essential toward maintaining a dependable and reliable space transportation system. We must now consider this issue in light of the embryonic U.S. commercial ELV industry. To what extent this new industry develops will surely impact the issue, as will the safety and reliability of our current orbiter fleet.

For years the private sector has demonstrated its ability to provide effective communications satellite service for our country and the world. To the end of maintaining our preeminent position in the world in this industry, we must determine the role of NASA in communications research and development. Our committee has long realized the importance of research and analysis in our space science and applications programs. Some of our more expensive and glamorous missions will hardly be worthwhile if we are not willing to make the modest investment for fundamental supporting research at our universities.

While the President's budget contains a healthy increase in aeronautical research and technology, we must insure that these resources are properly directed to meet the continued and increasing challenge of foreign competition in aeronautical technology and sales. Clearly these are some of the issues in which this committee has an interest.

Therefore, we are pleased to welcome Mr. Jim Beggs, NASA Administrator; Dr. Hans Mark, NASA Deputy Administrator; and Mr. Tom Newman, NASA Comptroller.

Before we hear from them, however, Senator Heflin, do you have any remarks?

OPENING STATEMENT BY SENATOR HEFLIN

Senator HEFLIN. Mr. Chairman, we begin the first of 4 days of hearings to consider NASA's budget request for the fiscal year 1985. NASA is requesting $7.5 billion, which would be a 4-percent increase for this year. This budget would barely keep up with inflation. Compared to the National Science Foundation and the DOD research and development budget, NASA's increase is, indeed, very modest.

As I meet and talk with people in my State and elsewhere, I find that budget deficits are on everyone's mind. It is a national concern, and everyone must do their part in controlling expenditures. In this regard, NASA's budget is an example of discipline. We must remember, however, that certain expenditures are actually investments, investments that return significant benefits often manyfold, greater than their cost. Supportive research and development in NASA are examples of these types of investments.

The people of the United States seem to agree with this assessment, according to a December 1983 Harris poll. It reported that 68 percent of the American public believed that the Government

funds for research should be increased by a sizable amount, even in this era of soaring deficits. The American people are optimistic about science and technology. Of the random sample of 1,256 people that the Harris poll surveyed, 83 percent believed that science and technology in the past has done more good than harm. An overwhelming majority believe that recent developments such as computers, genetic engineering and lasers will improve the quality of their lives. Moreover, 70 percent of those polled even said that they thought a permanent space station would improve the quality of life, though they did not say how.

I would include myself among those who believe that a space station would be in our national interest to maintain leadership in space and in technology, but I would caution my colleagues that a space station by itself would not insure continued U.S. leadership. We must have and we do need a balanced space program. I believe NASA understands the importance of a balanced space program.

The administration's plan to keep NASA's budget at about a 1 percent growth rate in constant dollars is worth studying. It is budgetarily conservative. It could permit periodic new starts such as a space station. We also need those new initiatives in science, applications, propulsion, advanced technology and aeronautics.

Mr. Chairman, I know you share my concerns in keeping NASA's space and aeronautics programs healthy and balanced. I look forward to these hearings and listening to these witnesses.

Senator GORTON. Senator Trible?

OPENING STATEMENT BY SENATOR TRIBLE

Senator TRIBLE. Thank you, Mr. Chairman.

I, too, would like to welcome our distinguished witnesses today.

I have just a few words, if I might, Mr., Chairman. The NASA budget request contains programs intended to maintain America's leadership in aeronautics and space technology. Most prominent among these is the space station initiative, the program to become the cornerstone of the visionary strategy that will reap unlimited benefits for our Nation. I strongly believe the space station will provide the technological impetus for commercial development of space.

Some might question the cost of that space station. However, realizing the potential of space-based technology means significant improvements in electronics, pharmaceuticals, materials and communications industries. It is an investment that a great nation must make.

Another element of the NASA program of real importance is the aeronautics research and technology. NASA has contributed mightily to our Nation's leadership in civil and military aviation. We should not, however, take our leadership role for granted as foreign competition is becoming ever more sophisticated and making greater inroads into the domestic marketplace.

This year's aeronautics request is 13 percent higher than last year. I would support such critical aeronautics technologies as advanced turboprop and laminar flow control. Adequate funding for NASA today lays the groundwork for tomorrow. It will spur economic growth and expand our scope of knowledge.

So I look forward to the testimony of these witnesses today, and I hope this committee will support this program. It is important.

Senator GORTON. Senator Lautenberg?

OPENING STATEMENT BY SENATOR LAUTENBERG

Senator LAUTENBERG. Thank you, Mr. Chairman.

I, too, welcome the panel and look forward to their testimony, and I am looking forward to exploring the NASA programs for fiscal year 1985.

The keystone of this year's effort is, of course, the proposal to commence work on a manned space station. We have a request for $150 million for the coming fiscal year. The program costs are estimated to total somewhere around $8 billion, and of course, that is greeted with a degree of concern, if not skepticism. Questions have been raised about the technological returns on a program of this scope. Concerns have also been expressed about possible military applications of the manned space station down the road.

One might also question whether the administration is promoting the manned space station at the expense of other critical programs already under way. I am most disturbed about the agency's turnabout in satellite communications. Last year NASA presented a plan to develop an advanced communications technology satellite [ACTS] to be launched in 1988. The program was designed to maintain American preeminence in satellite communications technology. It was designed to continue NASA's traditional role in developing new, high risk technologies that form the foundation for commercial development, the kind of foundation upon which a multibillion dollar high-tech industry has been established. The ACTS program would meet the increasing challenge from our competitors abroad.

Last year we authorized the ACTS program. By this time, NASA told us, the contracts would be signed; the program would be embarked upon a 1988 launch. NASA last year projected a request for fiscal year 1985 of $90 million. Instead, NASA has decided to ground and downgrade the program. It is requesting only $5 million for an undefined ground-based program. It is no secret that the administration is hanging its hat on a proposal by Hughes to fly a satellite in the Ka band, and as I think it will become clear when we proceed in these hearings, the Hughes filing is no substitute for the ACTS program.

Meanwhile, however, the ACTS program is at a standstill. Notwithstanding the clear intent of Congress to get to work this year on ACTS, the ACTS program has been in limbo since December without congressional approval. Indeed, no request has been made to the Congress to reprogram existing funding. Perhaps that is because every member on this subcommittee went on record last month in opposition to any reprograming.

In the broadest terms, our consideration of the ACTS program raises two questions: Are we committed to preserving American preeminence in satellite communications technology, or are we prepared to relax our efforts just as our foreign competitors are redoubling theirs.

Mr. Chairman, this is a matter of deep concern to me. I understand that we will have a panel to speak about ACTS at a later date. I am eager to explore these issues with Mr. Beggs and his colleagues here this morning.

Senator GORTON. Mr. Beggs, we would be delighted to hear from you.

STATEMENT OF HON. JAMES M. BEGGS, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY DR. HANS MARK, DEPUTY ADMINISTRATOR; AND C. THOMAS NEWMAN, COMPTROLLER

Mr. BEGGS. Thank you, Mr. Chairman.

Mr. Chairman, members of the committee, I am pleased to be here to discuss President Reagan's proposed budget for NASA for fiscal year 1985. Although modest in growth, this budget is bold in spirit and farsighted in vision. It reflects the President's commitment to a forward-looking and imaginative initiative for the Nation. A permanently manned space station is the next logical step in space. Such a facility will give us a permanent presence in low Earth orbit in the early 1990's and will be the cornerstone of our activities in space through the end of the century and beyond. Inherent in this proposal is the President's vision of the future which embodies continued U.S. leadership in space technology, space exploration and the commercial uses of space while simultaneously encouraging international cooperation.

The President has proposed a NASA budget of just under $7.5 billion for 1985. This represents an overall increase of $274 million, or about 4 percent over our present plan for fiscal year 1984. The fiscal year 1985 budget also contains a positive step in terms of program outlook and institutional stability. The President's 5-year projections include real growth in NASA activity of approximately 1 percent per year over the 1986–89 period. These projections do not merely provide for the future year costs of programs proposed for this budget year, as was the previous practice, but include an allowance for the future new initiatives that are essential to a vital program of leadership in space and aeronautics.

I would call your attention in particular to the growth allowance reflected for ongoing and new science and applications programs. While the overall projected growth in this budget is modest, it will allow us to undertake and accomplish the space station effort, and will support a vigorous space science and technology program through the introduction of a number of new initiatives during the 5-year period. This approach gives us an opportunity to plan and implement a forward-looking program and provides added incentive to our people to make it happen.

The President's multiyear estimates recognize the importance of stability and long term commitment for maintaining NASA's research and development base as well as for realizing the fruits of high technology investments.

The space station initiative announced by the President in his state of the Union message to Congress will reflect and contribute to America's commitment to research, technology, and productivity, be a peaceful, visible demonstration of U.S. strength, implement

the clear direction of the civil space policy as needed and found in the President's national space policy set forth in July 1982, which reflects a thorough review of our long range goals and plans in space, provide new capabilities for science and applications, thereby continuing the tradition of scientific achievement and excellence which the Nation has come to associate with the space program, and enhance the opportunity for commercial investment and economic return of space-based research and processes.

The time for a space station is ripe. The agenda for tasks which can be undertaken and enhanced using the unique capabilities of the space station is full, and both U.S. industry and the NASA institution are fully prepared to implement the President's initiative. The station is, I believe, the next logical step in space.

The most important reason to begin a space station now is that the space shuttle is approaching full operational status. To maximize the unique advantages provided by the environment of space, we need to establish a permanent presence that enables us to work in space, full time, and fully utilizes the capabilities of the space shuttle. The second reason is that the operations we have conducted with the shuttle have stimulated great interest in the private sector to look toward investment in future space activities. The construction of a space station is necessary to create the facilities that will greatly encourage such investment and stimulate new technology that will spin off into the U.S. economy. The space station will provide a threshold for significant commercial exploitation of the space environment. Finally, the shuttle has also stimulated great international interest in the U.S. space program. As the President stated, we will plan the space station program in such a way that it will be possible for our friends and allies around the world to participate with us in taking this major step.

Based upon NASA and industry analysis over the last 18 months, the space station program will serve as a space laboratory and permanent observatory, transportation servicing and assembly facility, manufacturing facility, a storage depot, and a staging base for more ambitious future missions. Perhaps more important than any of these individual points, however, is that the space station, in my belief, will lead to important activities and functions that we cannot even predict today. The space station will represent a fundamentally new and versatile capability to support activities in space in the decade of the 1990's and beyond. Just as the use of communications satellites has revolutionized long-range communications during the past 15 years, I believe that the space station will open new areas in which the industrial use of space will become commonplace.

As we now see it, the station would consist of a manned base and associated unmanned platforms oriented to the needs of both science applications and possibly industrial missions, and man-tended from the base. We believe that the enabling capability of the space station can be in place within a decade for approximately $8 billion, in 1984, over the development phase.

For the fiscal year 1985, we are requesting $150 million for the space station program. These funds represent the minimum amount sufficient to begin an endeavor of this importance and scope and necessary to assure an efficient, well-conceived space sta-

tion program. As you know, we have planned an extensive definition effort with sufficient resources to assure that the program, when hardware development is initiated, will be thoroughly defined, responsive to user requirements and based on an effective mix of man and machine, incorporating the most advanced technology available.

Mr. Chairman, making the space shuttle fully operational and cost effective remains NASA's No. 1 priority. The space shuttle has continued to perform splendidly. There have been major achievements in the past year. Perhaps the most important was the first flight of spacelab, which was funded and built by the Europeans. Spacelab 1 flight demonstrated that people in space can perform very complex experiments and that real-time corrections and fixes to the experiments can greatly enhance our ability to get important scientific results. The results of Spacelab 1 confirm the capabilities of scientists in space to perform valuable experimental work, particularly when there are real-time audio communications between the onboard crew and their scientific colleagues on the ground. The mission gave credence to our plans for scientific utilization of the station.

Since our appearance before you last year, we have had five successful shuttle flights, which included the first flight of the second orbiter, *Challenger,* the first night launch and landing, and the first landing at the Kennedy Space Center.

We also conducted our first extravehicular activity from the shuttle, and it was very successful. We have learned much about the operational environment of the payload bay. It is our intent to put this knowledge to good use. STS–41B, the *Challenger,* flight launched February 3, successfully conducted the first untethered extravehicular activity to test the new manned maneuvering unit. However, on the same flight, two reimbursable communications satellite missions experienced anomalies. One of the affected satellites, Westar VI, was for Western Union and one, Palapa-B2, for the Indonesian Government. These missions were successfully launched out of the orbiter bay, but because of an anomaly believed to be in the commercially provided spacecraft's payload assist module, called PAM–D, the spacecraft did not achieve proper orbit. The causes of these failures are under investigation.

In fiscal year 1984, seven or eight shuttle flights are scheduled. These flights include the first dedicated Department of Defense mission, the first flight of space shuttle orbiter *Discovery,* the first autoland, and the deployment of seven commercial communications satellites. Toward the end of 1984, *Atlantis,* the fourth orbiter is scheduled for delivery.

In fiscal year 1985, the space transportation operations budget provides for 11 space shuttle flights, including 3 dedicated space-lab missions; completion of the TDRSS constellation of 3 orbiting spacecraft; the deployment of 8 communications satellites; first retrieval of a shuttle-deployed spacecraft, a long-duration exposure facility; transition from the conceptual phase of the McDonnell Douglas electrophoresis experimentation to small prototype production plants that will produce products in quantities sufficient to begin testing and marketing; and continued use of the shuttle by the Department of Defense. The STS flight rates will continue to

increase toward a rate of 24 per year by fiscal year 1989 when we expect to launch about 20 from KSC and the remainder from the Vandenberg Air Force Base. The first flight from Vandenberg is planned for fiscal year 1986.

In view of the successful performance of the shuttle during the past year, I continue to believe that the investments we have made in the space shuttle system will pay off handsomely in the future. The shuttle has become the Nation's primary space launch system. Because of this, we are continuing the program to produce the spare parts required to assure a launch capability that is so important in both the civil and national security related sectors. We are also continuing the structural spares program which will make it possible to assemble another orbiter should the decision be made to take that step.

Mr. Chairman, I would now like to turn to NASA's more traditional programs and provide you with a brief report of our accomplishments in the past year and also give you a synopsis of our plans for the future. In our space science and applications program, the most important achievement was the successful launch of the infrared astronomical satellite, IRAS. It is a cooperative project of the United States, the Netherlands, and the United Kingdom. The mission, which was launched in January 1983, remained operational through December 1983, and made a number of important discoveries.

In our fiscal year 1985 budget request for space science and applications, we are proposing several new important initiatives. One is the upper atmosphere research satellite which is planned for launch in 1989. It will provide detailed measurements of the physical and chemical properties of the upper atmosphere. I believe that the upper atmosphere research satellite is the most significant new initiative in atmospheric science in many years, and I strongly recommend your support for that program.

Another new initiative is the Mars geoscience/climatology orbiter planned for launch in 1990. The mission will be designed to obtain new geophysical and geochemical information about Mars, especially near the polar regions where not much data is available. This mission is the highest priority of a number of relatively low-cost missions referred to as planetary observers which were recommended by the Solar System Exploration Committee to provide a more intensive investigation of specific questions in planetary science. I believe the approach we are taking on this mission will be both an efficient and cost-effective method of planetary exploration.

For several years now, we have developed plans for a program to fly an advanced communications technology satellite called ACTS which is designed to develop advanced communications switching processing and antenna technologies to retain U.S. technological leadership in this important field. This program was designed to be executed in close collaboration with the communications satellite industry. It has been our purpose, consistent with the President's policy, to encourage private sector commercial investments in space and to formulate our programs in such a way as to make it possible for private investors to take part in space activities. The ACTS program is an example of this policy. Recently private com-

panies have made proposals to build satellites with their own money that will do some of the things that we had planned to do with ACTS. In view of this development, we have decided not to request funding to support a flight demonstration which had been planned in the ACTS project, but to continue the necessary-related technology activities on the ground.

The proposed fiscal year 1985 space science and applications budget will continue to support the Hubble space telescope development activities leading to a launch during the second half of 1986; the Galileo development activities leading to a launch in 1986; development of the Venus radar mapper; and, the gamma ray observatory, both of which are scheduled for 1988 launches. The budget will also continue to support spacelab instrumentation and other shuttle payloads, life science, and microgravity science applications, and a strong and diverse supporting research effort.

The fiscal year 1985 request for aeronautics research and technology will provide the technology advances critical to the continued preeminence of U.S. civil and military aviation. The planned program provides a solid base of fundamental research in the aeronautics disciplines—aerodynamics, materials and structures, propulsion and controls and human factors—and systems research directed at the interactions among components and subsystems. Vehicle-specific areas of NASA research include subsonic aircraft, high performance supersonic cruise maneuverable aircraft, and rotorcraft. Current activities are directed at improved performance, safety, and reduced costs of aircraft and operational systems.

Our fiscal year 1985 aeronautics request continues important new initiatives begun in fiscal year 1984 in numerical aerodynamic simulation, advanced composite structures technology, technology for the next generation of rotorcraft, and the advanced turboprop program.

The fiscal year 1985 space research and technology request provides a broad base of long-term, high-risk, high-payoff technology essential to NASA's role of maintaining U.S. preeminence in space. Of particular significance in this year's NASA program are advanced technology capabilities derived from ongoing research which will be focused in support of space station definition efforts.

The space tracking and data systems fiscal year 1985 budget will provide for the continuation of the vital tracking command, telemetry, communications, and data processing support to meet requirements for all NASA flight programs. Tracking and acquisition of data functions are presently accomplished through the use of a worldwide network of ground stations and by the first of a series of three tracking and data relay satellites. Last year TDRSS-1, which as you know had a very difficult deployment, has successfully supported Landsat 4, the STS-8 mission, the STS-9 spacelab 1 mission, and the STS-41B mission. The spacelab mission received 99 percent of the requested mission data acquisition support. While we are still working with the U.S. Air Force to resolve the inertial upper stage problem, we hope to launch the next TDRSS in early 1985 with the third TDRSS launch to follow later in 1985.

NASA's fiscal year 1985 construction of facilities request will provide for minimum essential facility needs with particular emphasis on exploiting the Shuttle's capability, enhancing key re-

search facilities for aeronautics and space technology, and improving space communications capabilities.

Mr. Chairman, I am very pleased to report that the NASA institution is fully prepared to support the President's budget initiative. Perhaps the most important factor is that with the support of this administration and the cooperation of the Congress, the decline in the civil service complement assigned to NASA has been stopped. For the past 2 years the NASA civil service complement has been stable at approximately 22,000 positions. Our fiscal year 1985 research and program management budget request will allow us to continue with this number of people into the future and to do the most important thing that we need to do, and that is to hire a substantial number of fresh-outs to bring the creative young people into the program.

Mr. Chairman, I have attempted to provide you and the members of the committee with a short overview of the administration's fiscal year 1985 program for NASA. I believe it is an excellent program and will continue to insure our Nation's leadership in space and aeronautics in the coming years. The program also provides a new vision for the future which is both realistic and farsighted.

I would be remiss if I did not take this opportunity to thank this subcommittee for its continued interest and support. Without your help and leadership over the past years, it would not have been possible for us to formulate the program that I am presenting today.

Mr. Chairman, I would be pleased to answer any questions. That concludes my prepared statement.

Senator GORTON. Mr. Beggs, the President, with your enthusiastic support, has requested that we authorize a manned space station. There are other proposals not involving or simply ignoring this manned dimension and which would either direct themselves at an automated space station or propose an automated space station which might later be developed into a manned station, and there are other proposals for the way in which to reach this goal.

Will you comment on those alternatives and speak specifically on what you consider to be the significance or importance of having a manned presence in space on a permanent or semipermanent basis?

Mr. BEGGS. Yes, sir.

Obviously when NASA initiated studies on the space station, we looked at a whole range of different options. I do not believe that there is any real opposition or even disparity between the idea of highly automated facilities on a space station and the idea of manned operations. We are and have over time in all of our manned programs tried to automate to the highest degree possible so as to increase the productivity of the men in space. The space shuttle is an example of that. We have any number of automated capabilities on the shuttle which allow the crew, while they are in space, to do far more than they could otherwise do. NASA has studied space stations going back really 20 years or more, and there are a number of studies that consider the degree of automation that we thought appropriate and the degree that they ought to be manned.

I believe that a number of things which have happened in connection with the space shuttle, most particularly pointing to the spacelab flight last year, point to the many reasons why people are required in the loop. Human intelligence is enormously important. They are able to make unforeseen adjustments in equipment. They are able to make repairs. They are able to change the thrust of a particular activity when it becomes obvious that the preparations for that particular activity are going amiss. The human intelligence, I think, is an essential part of the activity, and it should be there from the beginning. If we proceed with a totally automated station, it may be possible to do certain things. But, I would point out that of all of the automated spacecraft that we have sent up, a fairly substantial number have failed in one way or the other, and the ability of human intelligence to correct and repair is an enormous advantage in continuing to keep those experiments, the observations, and the other things that we are trying to do operating at full efficiency.

There is another advantage, and that is that we can over time upgrade and improve. Technology is moving, as we always say, at an ever-accelerating rate, and the instruments that we launch today will be obsolescent in just a few years. Our ability to go up using, again, unmanned platforms to mount those instruments but yet be able to change them out, replace them, upgrade them, and also replace the consummables on board, is of enormous advantage and will certainly make them much more cost effective.

The overall experience of the spacelab, I think, was really eye opening. What we saw was a very close interaction. With the one TDRSS satellite operational, we were able to maintain contact with the spacelab almost full time. We had it in view for half of every orbit and then could record on tape the other half of the orbit. There was enormous interaction between about 150 scientists on the ground and the 6 astronauts who were working in the laboratory in space. And I think the success of many of those experiments, and the ability to work closely together in real time illustrated as nothing else can why human intelligence in space, working closely with the intelligence on the ground, can improve the productivity.

If you go back to the beginnings of our program 25 years ago and look at the amount of real, honest to goodness experimentation that we have done in space, it probably does not amount to much more than a month or two of the kind of interactive capability of a good industrial research laboratory or a university research laboratory. As we all know, many of the discoveries that we make in science and technology are unplanned, that is, they are not in the objectives that one sets out for the experiment but they are things which turn up in a serendipitous way as they proceed through the experiment. Our ability then to operate in the same mode that research facilities operate on the ground, I think, will result in many things that we cannot even predict today.

So I think the manned part is very important. You can do a lot in an automated way these days, but I take note of the fact that even our most automated factories—and we have looked at a number of them, both in this country and abroad—still require the presence of human intelligence to keep them operating properly.

Do you have anything to add?

Dr. MARK. I think you have said it all.

Senator GORTON. Would you describe the degree to which you will press for and the degree to which you hope for participation in the development and use of the manned space station by our friends and allies in Western Europe and Japan and comment specifically on whether or not they will develop technologies of their own or simply provide capital for us to do so, and also on how any such participation will impact on your estimate of roughly an $8 billion cost between now and initial operating capacity?

Mr. BEGGS. The Europeans, represented by the European Space Agency, Japan, and Canada have all indicated a very intense interest in what we are doing. They have carried on studies for the last year or more on their own, looking at ways that they can contribute and become a part of a larger effort. What we are doing in space station is new in the sense that in the past things like the space shuttle and the various unmanned scientific satellites on which we collaborated were activities that had a beginning and an ending, a clear start and a clear end, and once they had supplied the technology or the instruments or the pieces and parts of those systems that they provided, their job was essentially over. To be sure, they participated in the analysis of the results, and we have invited them, of course, to continue to have access to data on not only the programs to which they have collaborated, but other programs.

The space station will be different in that they will not only collaborate in the development of the station, but they also have the opportunity to become a part of the ongoing activities once the station becomes operational. It will be truly, or can be truly, an international venture in the sense that they will fly with us, that they can develop continued experiments for it, that they can participate in the industrial activities connected with it, and that they can continue in the ongoing science activities connected with the station. I believe that is very important. I think that is why they have indicated a strong interest.

If they are to participate, however, in a major way—and I hope it will be a very major way—they will expect to get some scientific and technological returns from it. If they invest heavily, they will expect a return on that investment just as we expect a return on the investment we put in. And so, they will be looking for specific pieces of the system where they can reap some technological advantage or some industrial advantage. It will be a tough negotiation in that respect. We will have to be very careful. We have had a lot of experience in setting up international cooperative endeavors in space over the last 25 years. In fact, almost every major program we have carried on in NASA has had international participation. And I believe that if you look at that program you will see that the United States has gotten at least as much benefit from the collaboration that we have done with our friends abroad as they have received from us. And I believe strongly that we can do the same thing here.

With respect to the third part of your question which addressed the amount of money, it is our belief that the investment that the United States should make should be in that $8 billion range. What the Europeans, the Japanese or the Canadians are willing to

invest could impact that, but I would like to think that it would be in addition to that, to enhancements, additions to and so forth. But we are going to look at both. We are going to look at places where they can take part in the activities which we have more or less considered to be within the $8 billion baseline and those activities which could be enhancements to that activity.

Dr. MARK. Mr. Chairman, if I may, I would like to add one personal point here. Last summer, you may remember we took the *Enterprise* to Europe; that is the approach and landing test vehicle. We flew over with the *Enterprise* mounted on top of the 747. The popular response we had was quite overwhelming, and the interest that people in Europe showed in our programs was enormously surprising. Over 2½ million people came to see the vehicle at the airports where we stopped. At that time I talked to many technical people who had already some feeling for how technical collaborations could be made, but I want to stress one point, that the space activities we conduct using the shuttle create abroad a very, very positive impression of this country. So I think the idea that we create this space station as an international effort is something that will not only bear technical results, but it will also be important for our foreign relations and for our foreign policies.

Senator GORTON. Thank you.

Mr. BEGGS. I would add, if I may—this may get to be an overlong answer, but the experience we have had in flying the first of our non-American astronauts from Germany had enormous impact in Europe, not just in Germany, although obviously it was covered intensively in Germany, and a lot of real-time television in Germany, as well as tape playbacks on the television throughout Europe, and the idea that a European was flying, and not just any European, a European scientist was flying, just had an enormous positive influence. Almost every country with which we do business is interested in flying an astronaut on the shuttle, and we are going to fly a lot of them. We are going to fly the second one, a Canadian, this year, and then we will be flying probably three or four more each year as the flight rate builds. And, I think that not only the potential of their citizens flying not only on the shuttle, but also to a space station and spending time on a space station doing whatever they will do, experimentation, industrial activities or whatever science they desire to do, will help keep a very live image of the United States and our accomplishments as well as the importance of this close family that we have with the Western Europeans, Japanese, and the Canadians.

Senator GORTON. Even though the Department of Defense has said that it has not identified any specific military requirements for a space station, will DOD still have preemptive rights on a space station as it has on the shuttle?

Mr. BEGGS. They have indicated no desire to take preemptive rights. Obviously any technology that comes out of a space station that has military application we would pass on to the Department of Defense, as we are required to do by law, and we take that very seriously. We will continue to keep them informed, and they have said that they would like to continue to observe.

Now, you must remember, Mr. Chairman, that we are proposing this initial capability in a low inclination orbit, the usual 28½

degree inclination. That is not a useful, or not a particularly useful orbit for military operations. The military much prefer higher inclination orbits, for obvious reasons. I think that if they get interested in the idea, the technology and the development efforts that we carry on on the civil side, they may very well pick up what we have designed and developed and the technology which has come along and do their thing themselves. I think that would be rational and reasonable for the future.

I see right now no major DOD interest in the program, and I anticipate, no DOD desire to take any kind of preemptive rights. If there were an urgent defense need, however, I guess we would look to what that need was, what that requirement was, and try to accommodate it.

Senator GORTON. On a different subject, Mr. Beggs, NASA requested $41 million for the advanced turboprop program, but the budget, through OMB, shows only $14 million for that for 1985.

Can you tell the basis for this reduction, how long it will delay a flight test program for the advanced turboprop, and what effect this delay is likely to have on U.S. commercial aircraft and the U.S. commercial aircraft industry's rather narrowing lead in international competition?

Mr. BEGGS. Well, the thing that was denied us was the phase III flight program. This goes back to a philosophical and policy argument I guess that we get year after year on flight programs. The basic difference in position usually is: "Is a flight program really necessary to encourage and motivate the industry to pick up this new technology and move out with a commercial project; and second, if we proceed with it, do we have to go all the way, if you will? Can we not go just part of the way toward test beds and what have you to accomplish the same thing, that is, to bring the technology to the point where someone will pick it up and use it?"

It has been the NASA position for a long, long time that most of the more advanced technologies require a proof of concept stage which in the case of aeronautics translates to some kind of a flight program. Flight programs have taken any of a number of characteristics over the past decade or so. We have flown experimental aircraft with the Department of Defense, and indeed, we are going to start flying one here in the coming year in the forward-swept wing, the X-29, and we have had collaborative efforts in the civil transport field with a number of companies in trying to adapt pieces and parts of our technology to commercial transports and done a lot of work.

In the case of the advanced turboprop, the reasoning was that it was too early to know whether the industry might pick this up or not and that it was not judged to be an imperative or particularly pressing investment to move to the flight test program. However, it was agreed that we would continue our research and technology development efforts in the advanced turboprop looking to the possibility of putting an engine with an advanced turboprop on some kind of an airplane, maybe in a cooperative way or possibly as a specific experiment in the future. But it, as I say, was considered to be somewhat too early to go to the phase III program this year.

Senator GORTON. Even though the budgets for physics and astronomy and for planetary exploration show healthy increases in

this budget request, within each of these budgets the funding for research and analysis has either decreased or remained static. Because that is so important to basic research for both universities and national laboratories, how can we justify not only this level of funding for research and analysis, but the balance within the physics and astronomy and planetary exploration sections?

Mr. BEGGS. Well, I don't think you can, Mr. Chairman. I guess we have got to get together on the figures. My figures show a small increase in the R&A budget, maybe not as much as folks would like. Now, there are puts and takes within the R&A area where some decrease and others increase slightly. Overall, the total R&A budget is up a little bit. It goes from, by my figures, $255 million to $260 million.

The planetary effort is down just a little bit, going from about $59.5 million to $54.5 million. The reason for that is that we have wedged a new start into the planetary program, which is why that particular line came down a touch. There are two ways we give support to the scientists in the area of research analysis and the kinds of things that they do in carrying on their scientific investigations. One is through the R&A line, which has been an ongoing program. I do support this, and we have tried to make a modest increase in it each of the past 3 years; I believe we have succeeded in doing that in the overall. The other way we do it is in the flight programs themselves where we have a line item for mission operations and data analysis which also has been increasing as we have initiated new programs.

I guess in summation, there is a desire to keep this going at a higher sustained level. In real terms, it is down somewhat from where it was in the mid-1970's, but then again, the overall NASA budget is down from what it was in the early-to-mid-1970's. Overall, in this budget, we have increased basic research substantially. As a matter of fact, the R&D effort, which is really R&D in this case because we have taken out the ongoing STS production and operations moneys and put them in another line, is up substantially. It is the biggest increase on a percentage basis we have in the NASA budget, and our university funding activity is proposed to be up in this budget.

Can you think of anything?

Dr. MARK. No; I think that is substantially right.

I might add one point. This issue tends to be controversial, and I think one of the things one has to remember is that there are fluctuations, even though the budget levels are constant or maybe even increasing a little bit, in the nature of the program that some groups will lose funding when a program is finished and other groups get started. For example, we have stopped funding the groups that work on the high energy astrophysical observatories which we launched, what, 6 or 8 years ago now because the work is essentially finished. At the same time, we have put massive new moneys into the space telescope effort where we actually built a new institute out at Johns Hopkins University to support that work.

So one of the problems you have is that when you look at this area you have to look at the fluctuations, and you will get com-

plaints from people who are really terminating efforts, and unfortunately, you don't hear from those who are starting up.

Senator GORTON. Thank you.

Senator Heflin.

Senator HEFLIN. Thank you, Mr. Chairman, and Mr. Beggs, I appreciate your testimony.

I anticipate that we are going to have a pretty good congressional battle over the space station. Already the debate nationally has begun, and there are those who are articulating alternatives, some more expensive, some less expensive, some farther away.

I believe it might be helpful for this committee to have an evaluation of the proposal that NASA is making, the $8 billion long-range proposal, as compared to alternatives. Some of these alternatives may have to be considered. Some of them may come up later on.

I think it would be helpful if we could have also the process of study that NASA undertook in evaluating and the elements of the decisionmaking that NASA involved itself in in making the decision for the proposal that the President has now supported and which is being proposed to Congress.

Maybe a statement as to the time of study, the kind of alternatives involved in this. Now, I realize that this is something that will take a little time, but could you maybe address, and I think briefly would be the proper way, the evaluation mechanisms, the alternatives that were considered while you came down on the proposal that you are making relative to the space station.

Mr. BEGGS. Yes, sir, Senator Heflin. We have, in the last 3 or 4 years—it has been intensified in the last 2—been looking at first what we could do with the shuttle. Four years ago we were anticipating the first flight of the shuttle, and we knew we were going to start the operational period of the shuttle, so it was important that we look at what we could do to exploit the full capabilities of the space shuttle and then to go beyond the capabilities that we could get out of the space shuttle to a more permanent presence in space, and then to carry that to a permanently manned or permanently occupied space activity.

As I said in my prepared remarks, I said a number of times we have been studying the idea of space stations for a long time, going back to the origins of this agency. During the days when we were planning Apollo, there was a very significant part of the NASA team at that time lead by Werner von Braun who proposed that the best way to do that Apollo mission was first a space station and then a direct ejection from the space station to the lunar surface. Indeed, if you look at that from the point of view of efficiencies, it is the best way to do it. It still would be the best way of going back to the Moon if you wanted to go back, and the reasons for that are fairly straightforward and, I think, have been reviewed in the past, but basically they relate to the fact that once you are in lower earth orbit, you can from the most efficient energy point of view eject onto the lunar surface.

So, there was a lot of interest in the space station. The reason we did not go that way in the Apollo days was that it would have taken too long. The President, President Kennedy, had committed us to a landing on the Moon within a decade, so that time impera-

tive is what caused us to do it with a lunar orbit and a lunar ejection from the lunar orbit. We have been studying space stations ever since. We have looked at various ideas and various concepts. The reason we have is that it is, as I have said, maybe to the point of being overly repetitive, the next logical step in space. The space station allows you to do a lot of the things, open a lot of the options that you would like to take up at some time in the future.

I believe that this Nation is going to want to continue to explore indefinitely, because it provides a tremendous incentive for technology. It provides a tremendous incentive for our activities across the board in industrial applications and, of course, it motivates and excites our young people, which is probably the most important of all. So, in order to make those things possible into the 21st century, into the third millenium, if you will, a space station is an essential part. Now, in setting that up, Dr. Mark and I sat down and said: "How should we go about this?" We did it in two ways. First, we organized a group within the agency headed by John Hodge which drew on all of the centers which had any input into that. That is just about all eight centers that we have. We gathered them together on a temporary basis rather than trying to put it in any one center.

We had, under John's leadership, started the study again looking at all the past work, projecting what the technology was likely to be in the next 10 years, taking a look at what the shuttle enabled us to do, and looking at everything from the extended duration orbiter through automated platforms and automated stations into the fully permanently manned station that finally resulted from the studies. In addition to that, we asked Dr. Jim Fletcher, who as you know was a former Administrator of the agency, to organize an outside group to take a look at it. He had a group of very knowledgeable and, I hope and believe, astute observers of the space station from all of the constituencies that we serve and believe are important. They came from the science community. They came from the industrial community. And they came from the NASA community, that is, ex-NASA folks who had gone off to do greater things, in any event different things, and some military folks, to take a look at it as well.

Both of these groups came to a similar conclusion, that is, that it should be manned. The other alternatives provided some capability but not the complete capability that you would want when you got out into the 1990's. You could extend the duration of activities of the orbiter up to 3 weeks or so. It would cost a penalty in payload, but it could be done, and it does enable certain things to be done. In particular, it enables you to observe a complete rotation of the Sun, for example, for the study of solar activities. It allows you to do some long duration experiments on crystal growth and some of the other industrial experimentation that you would like to do, but it really does not carry you very far beyond that. It does not allow you to do the very long duration experimentation that you would like to do, and it is difficult to extend the duration of the orbiter, and you may want to do that.

To extend the duration of the orbiter is as much limited as the 14-day capability that we have today. It is small, and it is limited in the number and the size and capability of the experimentation

you put aboard. So we felt that the extended duration idea was not worth the amount of money that we would have to spend on it, that we should proceed directly to the permanently manned facility. We also looked hard at the fully automated facilities and felt that the presence of the human intelligence was enormously important. I spoke on that earlier, and I think that all the folks who were involved in those things feel that way, that a straight automated station does not give you the full advantages that you have when you put the human intelligence on board.

The other thing I think we have to take cognizance of is that the large manned activities are the item that attracts people's attention. It is where the international community focuses their interest. I was interested in chatting last year when we had—as Dr. Mark said when we had the *Enterprise* in Europe with a number of European leaders, and they had quite a number of other political leaders. There seemed to be a change in perception. Some of them previously said, we do not need manned activities, we can proceed in the unmanned direction forever, and particularly the French, who have been a very large part of the opposition to manned activities in the past, had a change of heart. It was, I think, just a few months after the Paris Air Show, where the *Enterprise* showed up, that the French leaders came out and made a statement that they felt that a large part of the future in space had to be manned, and that they had to participate. Then they said, we will either participate in that activity with the United States or if the United States does not want, we will do it with the Soviets, which is a nice, French-like statement.

In any event, that change in perception, I think exists today. In fact, it has been accentuated with the flight, the first flight of the spacelab and the flight of the European astronaut aboard the spacelab. It is the area where the general public takes a great interest, certainly the interest among the students, the young minds that will come along and do the great things that we are expecting for the future, in that activity. It attracts their attention. It motivates them. It moves them to reach a little further and stretch a little further. I think that the bottom line where we came out is that it makes sense from a technical point of view and from the point of view of national prestige and national leadership. That is the area that attracts and motivates.

[The following information was subsequently received for the record:]

A permanently manned Space Station has been considered by NASA to be the next logical major step in the Nation's space capability development for many years. Various concepts of a habitable facility in permanent orbit have been studied throughout the history of NASA. In 1959 the concept was discussed as an alternative to a lunar landing program. At the close of the Apollo program a reuseable space transportaton system servicing a permanent space station was proposed as the next major step in the development of manned spaceflight capability. It was decided that the space transportation system be developed first with the initiation of the Space Shuttle program. As the Shuttle is reaching full operational status it is logical to now begin the definition of Space Station capability.

Over the past eighteen months in the course of Space Station planning activities, various alternatives to a Space Station have been studied. these alternatives were studied in the context of the requirements for the types of space missions that are foreseen for the decade of the 1990's. The basic alternative scenerios studies were: (1) the Shuttle operating with free-flying satellites, (2) the Shuttle operating with

unmanned platforms, (3) the Shuttle operating with this proposed Space Station, and (4) the Shuttle operating in conjunction with a much more capable Space Station. A brief discussion of each alternative follows.

SHUTTLE AND FREE-FLYING SATELLITES

This scenario is essentially "business as usual." It does not take the Nation significantly beyond the capabilities that exist today even if the on-orbit stay time and power of the Shuttle are extended by modifications to the Orbiter. This scenario does not fully satisfy the general requirements identified for possible missions of the 1990's, including long duration, manned microgravity laboratories for the development of commercial materials processing and life sciences research, a staging base for deployment and servicing of satellites at geosynchronous orbit, and a servicing/construction base for very large advanced telescopes and antennas.

SHUTTLE AND UNMANNED PLATFORMS

This scenario, including the Shuttle plus unmanned platform serviced by the Shuttle, does have significantly increased capability over that of the Schuttle alone. This is true whether or nor the Shuttle has extended duration and power. The major factor in the improved capabilities is the platforms. These platforms are especially useful for long duration astrophysics and earth sciences missions. However, this scenario does not have the capability to fully develop commercial materials processing in space, geosynchronous satellite servicing, life sciences research, or very large structures construction. These types of missions represent new technologies and research for the 1990's and require long on-orbit stay time with manned interactions.

SHUTTLE AND EVOLUTIONARY SPACE STATION

This scenario assumes a Space Station built and serviced by the Space Shuttle in a manner which enables the essential elements of the Station to be augmented over time, depending upon the demonstration that the need for such augmentations exists. A key feature of this concept is that there is a valuable set of misssions which will be accommodated within the Space Station's baseline set of capabilities. If and when the need arises, the Space Station could be expanded to permit larger crews, added power and laboratory modules, as well as deployment/servicing capability for spacecraft in geosynchronous orbit. The baseline set of capabilities would provide for accommodations for a crew of six to eight, 75 kilowatts of power, two laboratory modules, two platforms, and low-earth orbit satellite servicing capability. The baseline capability of this approach was selected by the President as being the appropriate level of commitment to a Space Station.

SHUTTLE AND FULLY FUNCTIONAL SPACE STATION

This scenario assumes that the evolutionary capability of the Space Station is fully exploited at the outset with all likely possible modules and equipment developed and placed on-orbit as fast as possible.

Commercial materials processing is developed in a continuously manned on-orbit laboratory and potentially in commercial modules attached to the manned base. Satellites are launched from the Station to geosynchronous orbit (GEO), satellite spares are stored on the Station for immediate deployment in case of failures in GEO orbit, and GEO satellites are serviced via an orbital maneuvering vehicle deployed from the Station. Astrophysics missions are accomplished on the manned base, the platforms, or on free flying satellites; very large telescopes and antennas are constructed at the manned base before deployment on the platforms or as free-flyers, and both the platforms and the free-flyers are routinely serviced. The nominal mode of operation is to refuel, repair, or reconfigure telescopes and other instruments on-orbit rather than to discard them. The long duration effects of weightlessness on plants and animals, including man, are studied and countermeasures for any detrimental effects are developed in a life sciences laboratory. Planetary missions are staged and launched from the station.

Senator HEFLIN. Recently you announced the lead center management approach for the development of the space station. Would you explain why you chose the lead center rather than the headquarters approach, and who will make the decisions, on what other NASA centers will do?

Mr. BEGGS. If I may ask Dr. Mark, he has had a lot more experience with this agency than I.

Dr. MARK. Senator Heflin, we considered the possibility of managing the space station program through a headquarters organization in Washington. You know, we did the Apollo program that way, so there is precedent for doing things that way. When we looked at it, we came to the conclusion that in order to do that we would probably have to put somewhere between 1,000 and 2,000 new people here in Washington on that job. We felt that was really inappropriate. You have to remember that right now our headquarters complement is about 1,400 people.

When we were doing the Apollo program, we had over 3,000 people here in Washington to manage that program. We decided, therefore, instead of making this massive change of moving people to Washington, all that which we could not do—we cannot get people to move that quickly—rather than do that that we would rely as we did in the shuttle program, on having the actual program management done in the field at one of the NASA centers.

As Mr. Beggs explained, the essential point here is to build a permanently manned space station. That is the objective, the lead. To do that, we really have to go to the place in NASA where that resides. That is the Johnson Space Center in Houston. All the other NASA centers will have important roles. In contrast to the shuttle, there is a much wider variety of things to do here. Let me just give you some examples.

The business of building a life support system that, for example, is partially closed. That would be the first time in a permanently manned space station. That would not be done in Houston. That would probably be done somewhere else. The power systems that we will have for generating electrical power, the guidance and control systems, the data handling systems, computers and communications systems, these are all subsystems that will be in a certain sense farmed out to other NASA institutions. We will be making judgments as to how to do this in the coming months. I expect it will probably take about a year to sort this whole thing out.

Senator HEFLIN. Does the lead center responsibility at this stage involve only the definition, or does it involve the development and design of hardware. Who is going to make the decisions as to what the activities of the other space centers will be doing?

Dr. MARK. Senator Heflin, the decisions as to what the other centers will be doing will be made here in Washington. That is a function that really Mr. Beggs and I have to do. Now, once a decision is made to assign a subsystem to a certain center, then it is the function of the lead center, Johnson in this case, to coordinate the work in such a way that the subsystem that is assigned to one center and the subsystem assigned to another one appear at the right place at the right time in order to be integrated into the entire station. It is very, very similar to the way in which we have always operated in getting large development programs going where we have normally a lead center that coordinates the thing, for example, in the Viking. The Langley Research Center was the lead center in Viking. However, the Mars orbiter that we had as part of the Viking program was farmed out to JPL. It was done in Califor-

nia at the Jet Propulsion Laboratory. So we expect to divide the space station program up in much the same way.

In the case of the shuttle, for example, the responsibility of the propulsion system was Marshall's. Although Houston was the lead center, Marshall had this very large responsibility of developing all the propulsion system. This was a very well worked out system. This is how we do business.

Senator HEFLIN. The first part of my question is, is Johnson's lead limited to definition or is it throughout the entire life of the development of the space station?

Dr. MARK. It will be throughout the life of the development program for the space station. Once we come into the operational phase, we may decide to operate it some other way, but in terms of the development program, Johnson will be the lead center.

Senator HEFLIN. Does this mean that the decisions as to the development of hardware and other things will be made by Johnson as to the other centers which are in competition with it, or does this mean it is going to be made at headquarters in NASA?

Dr. MARK. The decisions as to which assignment goes to what center are made here. Once those decisions are made, then it is the function of the lead center to basically coordinate the development and the production. That is the function of the lead center to see to it that all the assignments that are made are properly carried out.

Senator HEFLIN. Mr. Beggs, do you concur in his statement. I asked the question of you, and you referred to Dr. Mark, which is a little unusual for me, but do you concur with his statement?

Mr. BEGGS. I deferred to Dr. Mark because he has been closer to the institutional side, and I think you should hear that institutional point of view from him. I concur in what he has said. We will make the decisions on center assignments here in Washington. That is our intent. The reason that we decided to initiate this program in the manner in which we did was to do an extensive definition so that we could make those decisions as to center responsibilities and industry responsibilities in a very deliberate and rational way.

For the next couple of years, we will be pulling people from centers to work with us here in Washington as well as to work with the Johnson people from time to time in the expectation that we will fully define by that mechanism who will do what. The division of that as we see it in terms of manpower is spread throughout the agency. As I said, almost all of the centers will be involved in that, and the two that will be involved most significantly in the coming years, in fiscal years 1984 and 1985, will be Marshall and Johnson. After them will be the Kennedy Space Center from the point of view of the operations impact, then all the rest, Goddard, Langley, Lewis, and the others.

We have a breakdown on how we see that manpower today, Senator Heflin. We can make that a part of this record as well.

[The following information was subsequently received for the record:]

SPACE STATION—IN-HOUSE MANPOWER

[Fiscal year 1985 Congressional Budget Submission]

	Fiscal year—		
	1983	1984	1985
Johnson Space Center	100	150	200
Marshall Space Flight Center	109	125	150
Kennedy Space Center	24	75	100
National Space Technology Laboratories			
Goddard Space Flight Center	6	17	50
Ames Research Center			25
Langley Research Center			25
Lewis Research Center			25
Headquarters	9	9	25
Total	248	376	600

Senator HEFLIN. You are now into space commercialization. One of the concepts your task force recommended was national centers of excellence involving such areas as material processing in space. Would you go forward with such a program?

Mr. BEGGS. Yes, sir. That pretty well follows the philosophy we have had at NASA for some time. We have for the past several years been trying to upgrade and improve the various center operations in specific disciplines. We are working hard to make it possible for an industrial organization, particularly the nonaerospace industrial organization, to be able to focus or come into a specific center or a specific group in NASA and get answers to whatever questions they may have. We have a number of interested companies, nonaerospace companies who are working in various areas of material processing. We just signed up with a new one a few weeks ago, the 3M Co.

I think we are making good progress in this. The fact that we have—I forget the exact number, but 30 or 40—companies interested in pursuing activities with NASA for various types of space research and related research and technology development, I think, indicates that we are doing a reasonably good job.

Senator HEFLIN. I understand the Air Force is looking into a backup capability to the space shuttle. Specifically, they are planning to buy expendable launch vehicles over a 5-year period. What is the implication of this Air Force decision on the space shuttle, and what type of technology is the Air Force looking at? That is, will it be existing technology or modern technology relating to shuttle development, and to what extent is the Air Force involving NASA in its plan?

Mr. BEGGS. Let me try to start from the beginning on this one, Judge Heflin. The Air Force has from time to time conducted studies looking to the reliability of service—availability I guess is a better word—of the space shuttle on an emergency basis, a basis where you might need a launch in a very short period of time, and they are looking at it again. My understanding of their study is that they are looking at a backup to the shuttle in the form of an expendable launch vehicle, and they are looking at three options.

One is an upgraded Titan, a Titan Centaur which uses a seven-segment solid augmentation on the basic Titan vehicle. So it is a

taller vehicle, somewhat different from what exists today. They are also looking at an upgraded Atlas which goes by the name of Fat Atlas, because it is larger in diameter. It is also taller and of greater capability. I think you also use the Centaur stage. The other thing that they are looking at is one that NASA has brought to their attention, and that is a shuttle-derived expendable launch vehicle using the solid rocket boosters off the shuttle. The former two boosters are boosters which have been around for a long time. They are based on technology which goes back 20 years or more. They are still quite capable vehicles, but they are limited in growth beyond current capabilities. The current capabilities are impressive indeed. They have a lift capability comparable to what the shuttle can take. The shuttle-derived expendable does have significant growth potential. It would, if it were desired, provide capability up to several hundred thousand pounds in low-Earth orbit in the 1990's and beyond.

So, it does have the advantage of being able to grow over time, whereas the other two do not. I think the argument would be made, however, that since the other two are already available, that they are somewhat lower risk in development. However, it is our view that all three could be developed within a reasonable degree of risk.

There is another advantage to going the shuttle derived route. That is that you could use the same launch and production facilities that you use for the shuttle. Since you must maintain standby crews for the launching of these various vehicles, expendable or manned, it means that instead of two standing armies that could be available, you have but one, or maybe one augmented from time to time. There is an advantage there in terms of cost for the country and being able to rely on a single launch capability.

In addition to that, of course, to the extent that you buy SRB's off the production line, you soak up the overhead of the system, and you would by virtue of the learning curve perhaps bring the price down a little bit. So, there are substantial advantages to going that way. The impact on the shuttle could be severe, and I worry about that. The current projections are that the Air Force could be flying the equivalent of maybe 7 to 10 flights per year in the late 1980's on the shuttle. We have, as you know, put that into our manifest model. We put that into our market projections, and the loss of even two of those flights a year is something that I do not contemplate with any great feeling of joy. However, if it were restricted to two per year, I guess, it could be sustained if there are imperative needs for a backup, and that is something that I cannot judge. Only the Department of Defense can decide whether their needs are such that they have to have a backup.

I can only say that if they do need a backup, I would hope it would be one that would be overall to the best advantage of the country and the cheapest national alternative. The other factors which concern me are that there are economic arguments that could work against the shuttle. We priced the shuttle on a fixed-price basis over a period of time, so that the Department of Defense knows what it is going to pay, and in a given year the price for the shuttle is fixed, no matter whether they fly once or half a dozen times.

On the other hand, the expendable launch vehicle cost is very sensitive to flight rate, because the more they fly, the cheaper each individual flight is. Therefore, in any given year there would be, I am afraid, a tendency to say, "if we fly one or two more times on our expendable, we will save a significant sum of money." There is no saving overall most likely for the Nation, but there would be a saving for the Air Force by doing that. So that concerns me.

In summation, Judge Heflin, my feeling is that it would be highly desirable if they are going with the expendable—I would like to see them stick with the shuttle. I think we have shown them on the flights of the shuttle that we can provide service on schedule and reliably.

Senator HEFLIN. Mr. Chairman, I have a number of questions, but I will submit them in writing.

Senator GORTON. As will I.

Senator Lautenberg.

Senator LAUTENBERG. Thank you, Mr. Chairman.

Mr. Beggs, I come from the data processing industry, and we distinguish commercial data processing, that is, basic recordkeeping, from the science and engineering by the character of the process. In commercial processing, we put lots of input in, get very short runs and calculations and relatively organized, fairly large output. In the engineering side, you put small inputs, lots of calculations, and often fairly extensive output. I would like, if we can, sir, in the interest of time, to follow the commercial design. I would like to give a lot of input, get fairly short output, if I might.

Senator LAUTENBERG. And I would ask further, if you would kind of model your response to our typical admonition when we start the questioning process, which says, we will submit the long questions in writing. I would urge you, sir, to submit the long answers in writing, and if you could, give us a chance to make some time here. It is all in good humor, because I have a great deal of respect for the job that you do, you and your colleagues, and the full NASA program, but there is so much out there to be asked.

One thing that concerns me, very frankly, is, as we plan the projection for an $8 billion expenditure—let me say that I have rarely seen projections that are met on the low side, but if we have an $8 billion projection over a decade, do I understand the frame, the timeframe is approximately correct?

Mr. BEGGS. Yes, sir.

Senator LAUTENBERG. Then we will get an uneven expenditure over those years and therefore a single budget year could be as much as a billion dollars, if you divide 10 into $8 billion.

Would you say that in those years that we might be looking at a NASA budget that could jump as much as 15 percent, or might we have to come back or compress other programs? Obviously, all of your programs are vital. Might we be doing without things, or would you be bold enough, are you still the guy in charge to say, this year we have a 15- or 20-percent increase because our NASA space program is part of the requirement?

Mr. BEGGS. Our view is that we can hold within the budget projections that we have submitted for the 1985 budget year. What we propose is that we maintain a budget at current levels in real terms plus 1 percent per year growth over the next 5 years. The

reason we are able to do that is the shuttle expenditures for the development phase of the shuttle are now coming down. I think they will continue to come down, even if we required another orbiter. We think the amount of money would be adequate.

This program needs nothing so much as a steady-state budget. I will stack the record of this agency up against anyone, including an industry of any time, in terms of cost overruns. If you look at our programs, both major and minor, in the total sense we have had some large overruns, we have had some small overruns, and we have even come in under budget on a number of programs. And we believe we could do this.

Senator LAUTENBERG. I am willing to concede that you are pretty good on targets. But am I not correct—perhaps I have not made myself clear—if you have an $8 billion expenditure scheduled over roughly a 10-year period with $150 million scheduled for this year, that leaves a fair sum to be distributed over the remaining 9 years? Some year we are going to be around $1 billion.

Mr. BEGGS. $1½ billion to $2 billion, yes, sir.

Senator LAUTENBERG. Right. If you had to throw a short forecast out there, would you think that is realistic in terms of the budgetary forecasts that we see for our country in the next several years?

Mr. BEGGS. With the 1-percent growth projection, the 1989 budget projection for NASA, assuming the current figures for inflation that come out of the OMB, would be a little bit over $9 billion. Within that, we think we can accommodate all of the things that we projected in this budget. Obviously, we studied this very hard in order to make those projections. We do think that they are realistic. But the flexibility in the budget goes to the planning which is in those numbers, and there is a planning wedge in them. If we overrun on the space shuttle, it will impact that planning wedge. If we stay on schedule, we will have room for a number of new starts.

Senator LAUTENBERG. OK. I was interested in your statement in the section particularly regarding the ACTS program, that in light of what we have heard in past years. I would like to just read you a statement and see if it sounds familiar:

> NASA in 1982 refocused its space communications program on high-risk technology to insure continued U.S. preeminence in the field. The technology developed will be usable in multiple frequency bands and in a wide range of future communications systems required by NASA, other Government agencies, and U.S. industry.
>
> The first segment of the new program to be tested in orbit will emphasize high-gain, multibeam antennas. Development of the advanced communications technology satellite for flight experimentation is planned to begin in 1984 with a launch in 1988.

You are probably familiar with this statement.

Mr. BEGGS. I could have said it myself and probably did.

Senator LAUTENBERG. OK. Our President was the one, I think. He put that in his aeronautical and space report. But what we are seeing today is the kind of reversal in your agency's commitment to that communications technology, do you not think?

Mr. BEGGS. Well, not a complete reversal, but I will admit to a reversal. What we have in the budget is a continuation on that technology program. We have had a runout of somewhere in the $20 million to $25 million a year class, but entirely devoted to the ground. It will not fly.

Again, it goes back a little bit to the argument on the advanced turboprop. I think the philosophy that we are arguing is sound. The arguments on both sides make sense, but the issue is that when we have developed technology to a certain point that the industry is willing to pick it up and invest their good money in flying that technology or pieces and parts of the technology, then we should continue our technology development on the ground, but we need not demonstrate the concept.

Now, the argument to the side of that or in advance of that is, well, the industry is really not picking up all the technology. They are picking up only the pieces and parts that they see as necessary to supply the market at this time, and we want to advance that technology even further. We make that argument very vigorously in NASA and we made it in this case. But, the point that is made with respect to the marketplace is that it is not the Government's responsibility to anticipate the marketplace. It is only our responsibility to make the technology available and let the market forces decide what will be flown or what will be used in actual practice.

In fact, we had a responsive contractor who was willing to put down his money and file application for flying in the 20 gigahertz range. Admittedly, the technology that he is flying on that commercial project does not encompass all of the things that we would have flown. But, nevertheless, he is willing to fly. Now, the concurrent argument is that if we can put a satellite up which uses even more advanced technology, are we not trying to impact the market? Are we trying to influence the market, trying to change the market, and in effect trying to make his investment obsolete?

That is the essence of the argument on both sides, and we lost the flight program.

Senator LAUTENBERG. Except that NASA has initiated the programs, has been the leader, has caused our economic development to accelerate, I think, greatly. I was in my former life, I was in a business that used satellite communication and I know the impact in the general economy that that valuable opportunity presented.

Now I hear you saying something else. I hear you saying that a private commercial contractor might fly the thing. And I have to ask you a question: If this contractor tires or gets overextended, are you willing to cede the decisionmaking in this area to private or commercial interests, or have a private company make that decision on its own and leave us perhaps behind in a field where we now have preeminence, where it is essential that we maintain it?

There are programs that are scheduled under this technology, and I have a quote here that I think might be of interest. At a recent press conference you said that NASA was ready to downgrade ACTS in view of the Hughes proposal to fly the Kab and satellite. I don't know what particular victory you are talking about.

I want to read you a comparison of the proposed Hughes satellite and the proposed ACTS project, and it was, by the way, prepared by your agency's staff. Hughes' satellite provides technology essentially the same in 1986 as Japanese CS-1 and CS-2 in 1977 to 1983. The ACTS satellite provides very advanced technology designed to leapfrog European and Japanese technology.

Mr. Beggs, this is the question. Is it an American victory for NASA to merely keep pace with the Japanese and the Italians, or

is it a victory when we abandon the goal of maintaining, or abandon the decision on preeminence in satellite technology to the private sector?

Mr. BEGGS. If I felt that the Japanese, the Italians, the French, or the English were in advance of us or even up to us in this technology, I would be very much concerned. The plain facts are that the satellite that the Hughes people are proposing to fly is a better satellite than that the Japanese are proposing to fly. I believe that is true, seeing what is in that satellite. It is also true that what we were proposing to fly in the ACTS is far more advanced than that. But, we are continuing that technology, admittedly on the ground, and will make it available to anyone who wants to use it in this country to incorporate into even more advanced satellites.

The issue here is whether we ought to fly that technology. The argument for proof-of-concept is that you can develop a concept technology to a certain point on the ground, then you have to go fly it. If you do not fly it, you do not understand the interaction between the various pieces and parts of the system and you do not understand fully the propagation and the use of that technology when it is in actual operation.

But if in the face of a commitment on the part of a responsive industrial contractor we have proposed doing it, does it not constitute unfair competition? At least he would allege that it does.

Senator LAUTENBERG. I think when you start talking about something in the national interest, Mr. Beggs, although it is not directly analogous, there is certainly some relevance that we have gone in 1982 from a $280 million export surplus in telecommunications gear to a $200 million deficit in 1 year in the same field. And we all know that if we are not ever-vigilant that we are going to lose out in terms of competition to those nations who would put their national resources behind this thing.

It is this kind of a business, this kind of an industry, the ability to communicate—and of course, ACTS includes rural areas as well as the urban centers—that if we are not willing to do this high risk research, that we stand the risk of losing economic opportunity almost, without overdramatizing, if not forever, for many, many years.

When we talk about sharing these projects with other nations, when we see how often there are violations of protection of international property, we are taking I think some highly unusual risks when we invite partners in. And perhaps the appropriate analogy is the fox in the chicken coop example.

I am concerned about that. We are really playing for such large stakes here, and when we talk about the investment in this, it is a relatively small share of the budget, and when we talk then about the manned space platform we are talking about those who are eager to fly with us. I know lots of Members of Congress, by the way, a couple of good friends, who would like to fly in one of those things as well.

But the fact of the matter is that it is an American opportunity in all of these areas, and I think we ought to protect it by investing in it, by making sure that we have the qualities that all of us would be proud of, but also by protecting our flanks and not permitting those who are ostensibly partners to be ultimately the

users of the technology that we initiate and then our principal competitors.

I have other questions, Mr. Chairman, which I will submit. I want to just conclude by just kind of stepping back in time and ask Mr. Beggs a hypothetical question: That if you were the NASA Administrator in 1970, how would you react to the following scenario:

President Nixon gives the go-ahead to design and build a test model of the shuttle, to build the solid rocket motors, test them at Marshall, test a mockup in the wind tunnel at Ames, simulate takeoffs and landings at the Johnson simulator, test the tiles in the hot ovens. They are all pieced together at Cape Kennedy to conduct a ground flight readiness test, but you could not fly it.

Would you really have the confidence that that shuttle could fly, return safely to Earth? And if the private sector wanted to build a fleet of shuttles based on this scenario, they would have a heck of a time raising the money, let alone getting the insurance.

At this juncture, as I understand it, you are asking us in the case of ACTS to accept this ground-based program versus a flight test program as the more or less final conclusion.

Mr. BEGGS. With all due respect, Senator Lautenberg, I would suggest that it is a little different. We have been flying communications satellites for 15 years now very successfully. We still control the market. As a matter of fact, I do not believe there have been more than a very few communications satellites put into orbit that have not been either based on American design, American licenses, or produced by America. We still sell almost the entire market. We still control most of the market, and all of the satellites flown by Intelsat are American manufactured. I believe we still maintain a substantial lead in that field. That is not to mean that I would suggest that we rest on our laurels. Quite the contrary, I think we have got to continue to push this technology.

There was a time after the creation of Comsat that we got completely out of the technology. We just abandoned the field and said—and this was based again on the argument from some that the industry is now mature—that they will carry on whatever R&D is necessary. We found that we were falling behind and so we had to get back in it, and we are back in it. We are developing now what I consider to be very advanced and very good technology. The various and sundry pieces that we have—the base band processor, the multibeam antenna, the switching systems that we are coming up with—all are very good and very advanced.

The issue on whether we fly it—I think NASA would love to fly. They are always heartbroken and I am always heartbroken when we do not fly, because flying is what we love to do. It is the heart of our business.

But I argued hard for this program. There are some who say not hard enough, but I argued hard for this program, and if I see there was an existing industrial contractor willing to go forward with it and he was basing his decisions on the marketplace, and it was not my job as a Government bureaucrat to decide what the marketplace needed—therefore, we should not fly. But in making that decision, it was conceded that we should continue to push the technology.

Senator LAUTENBERG. I thank you for what I see as a very serious thread of candor through this. I think all of you know that it is really essential that that technology continue to be supported and stimulated, and we have an argument. I am not sure how it gets done, but it is essential.

Thank you.

Mr. BEGGS. Thank you.

Senator GORTON. Each of the members of the subcommittee is likely to submit additional questions in writing to you. We would appreciate your prompt answers. With that, we thank you very much.

We now ask for a panel of seven members of NASA's Aerospace Safety Advisory Panel, if they will step forward.

Mr. BEGGS. Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF HON. JAMES M. BEGGS, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Distinguished Members of the Subcommittee, it is a pleasure for me to appear before this Subcommittee to present President Reagan's budget request for NASA for fiscal year 1985. The total Agency request is $7.5 billion, of which $2.4 billion is for Research and Development; $3.6 billion for Space Flight, Control and Data Communications; $160 million for Construction of Facilities; and $1.3 billion for Research and Program Management. A chart summarizing NASA's fiscal year 1985 budget request is appended to this statement.

In his State of the Union message to Congress, President Reagan outlined a bold new initiative for the United States that will maintain and ensure, during the decade of the 1990's and beyond, our hard won position of leadership in space. The President's initiative is a permanently manned Space Station to be in operation within a decade. As a fundamental element of his vision for this Nation's future, the Space Station will:

Reflect and contribute to America's commitment to research, technology and productivity; be a peaceful, visible demonstration of U.S. strength and commitment to leadership; and implement the clear direction the civil space program has needed and found in the President's National Space Policy set forth in July of 1982.

The time for Space Station is ripe—the agenda for tasks which can be undertaken and enhanced using the unique capabilities of the Space Station is full, and both U.S. industry and the NASA institution are fully prepared to implement the President's initiative. The Station is, I believe, the next logical step in space.

The idea of a Space Station Mr. Chairman, is not new; however, a combination of circumstances makes the President's initiative especially timely. The most important reason to begin a Space Station now is that the Space Shuttle is approaching fully operational status. After a ten year development program, we now have the capability to reach low Earth orbit routinely. To maximize the unique advantages provided by the environment of space, we need to establish a permanent presence that enables us to work in space full time and fully utilize the capabilities of the Space Shuttle. Without the capability of the Shuttle, it would be impossible to establish the "more permanent presence in space" referenced by the President on July 4, 1982, in his National Space Policy statement. A second reason is that the operations we have conducted with the Shuttle have stimulated great interest in the private sector to look toward investments in future space activities. The construction of a Space Station is necessary to create the facilities that will greatly encourage such investment, and to stimulate new technology that will spin off into the U.S. economy. Finally, the Shuttle has also stimulated great international interest in the U.S. Space Program, as evidenced by the overwhelming reception of the "Enterprise" in Europe last summer and the recent highly successful flight of the Spacelab. As the President stated, we will plan the Space Station program in such a way that it will be possible for our friends and allies around the world to participate with us in taking this major step.

Based upon NASA and industry analyses over the past 18 months, the Space Station program will serve a number of functions, such as:

A laboratory in space, for the conduct of science and the development of new technologies;

A permanent observatory, to look down upon the Earth and out at the universe;
A transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
A servicing facility, where these payloads and vehicles are maintained, and if necessary, repaired;
An assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out;
A manufacturing facility where human intelligence and the servicing capability of the Station combine to enhance commercial opportunities in space;
A storage depot where payloads and parts are kept on orbit for subsequent deployment; and,
A staging base for more ambitious future missions.

Perhaps more important than any of these individual points, however, is that the Space Station, in my belief, will lead to important activities and functions that we cannot even predict today. The Space Station will represent a fundamentally new and versatile capability to support activities in space in the decade of the 1990's and beyond.

While definition of a specific Station configuration is yet ahead of us, it might be appropriate to describe conceptually what NASA now considers the Station to encompass. A Space Station is conceived as a multi-purpose, permanent facility in low-Earth orbit, that is comprised of both manned and unmanned elements and that significantly enhances the efficiency of our operations in space. As we now see it the Station would consist of a manned base and associated unmanned platforms, oriented to the needs of both science and applications missions, and man-tended from the base. The base and the platforms would be launched in modular sections carried into orbit in the cargo bay of the Shuttle. The Shuttle would also be used for logistics resupply and crew rotation. We believe that the enabling capability of the Space Station can be in place within a decade and for approximately $8 billion in today's dollars.

For fiscal year 1985 we are requesting $150.0 million for the Space Station program. We have planned an extensive definition effort with sufficient resources to assure that the program, when hardware development is initiated, will be thoroughly defined, responsive to user requirements, and based on the proper mix of man and machine, incorporating the most advanced technology available. These definition efforts will include an automation plan to utilize the best of both manned and unmanned modes to achieve optimum productivity at the Station. The fiscal year 1985 effort will include ongoing assessment of Space Station utilization requirements and initiation of a number of advanced development test beds to evaluate high leverage space station technology options. The fiscal year 1985 program will comprise the first year of this detailed engineering definition effort which will provide the basis for commitment to the final design for the construction of the Space Station. Mr. Chairman, we are very enthusiastic about the President's initiative, and look forward to working with you to make this vision a reality.

The fiscal year 1985 budget contains a positive step in terms of program outlook and institutional stability. The President's five year projections include real growth in NASA activity of one percent per year over the 1986–1989 period. The projections do not merely provide for the future year costs of programs proposed for the budget year, as was the previous practice, but include an allowance for the future new initiatives that are essential to a vital program of leadership in Space and Aeronautics. This approach gives us an opportunity to plan and implement a forward looking program and provides added incentive to our people to make it happen.

Mr. Chairman, making the Space Shuttle fully operational and cost-effective remains NASA's number one priority. I am very pleased to report that the Space Shuttle has continued to perform splendidly and that there have been major achievements in the past year. Perhaps the most important one was the first flight of Spacelab. The Spacelab-1 flight demonstrated that people in space can perform very complex experiments and that real-time corrections and fixes to the experiments can greatly enhance our ability to get important scientific results. The results of Spacelab-1 confirmed the capability of scientists in space to perform valuable experimental work and gave credence to our plans for scientific utilization of the Space Station. The ten-day mission met all of its verification objectives and obtained excellent scientific results. The flight was also an extremely important example of how complex international collaborative efforts can be successfully carried out. Mr. Chairman, the Spacelab was funded and built primarily by the European Space Agency and one of the people on the first Spacelab flight was a European scientist. The Spacelab flight drew a great deal of favorable attention in Europe and, there is

no doubt in my mind, it contributed to strengthening our relations with our European allies during a particularly critical time last year.

Since our appearance before you last year, we have had five successful Shuttle flights. During these flights, we flew the second orbiter, Challenger; made the first night launch and landing; accomplished the first landing at the Kennedy Space Center; and flew the first woman (Sally Ride), the first two blacks (Guy Bluford and Ron McNair) and the first two payload specialists including a foreign scientist (Ulf Merbold). We are now looking forward to the selection of private citizens as passengers on future Shuttle flights, possibly as early as 1985.

We also conducted our first extra-vehicular activity from the Shuttle and it was very successful. We have learned much about the operational environment of the payload bay and it is our intent to put this knowledge to good use. STS-41B, the Challenger flight launched February 3, 1984, successfully conducted the first untethered extra-vehicular activity to test the new Manned Maneuvering Unit. However, on the same flight two reimbursable communication satellite missions experienced anomalies. One of the affected satellites was for Western Union (Westar VI) and one for the Indonesian Government (Palapa-B2). These missions were successfully launched out of the Orbiter Bay, but because of an anomaly believed to be in the commercially provided spacecraft's Payload Assist Module (PAM-D), the spacecraft did not achieve proper orbit. The causes of these failures are under investigation.

On STS-41C we will retrieve a failed satellite (the Solar Maximum Mission satellite), bring it to the Shuttle and attempt to make the necessary repairs. If the repairs are successful, we will redeploy the satellite. If they are not, we will bring the satellite back to the ground for repair and redeploy it on a subsequent Shuttle mission. These operations are extremely important, not only because they will permit the extension of the lifetime of this valuable satellite, but also because they will be a dramatic demonstration of the great capability that is inherent in the Shuttle system.

Including the SMM repair mission, seven or eight Shuttle flights are scheduled for fiscal year 1984. These flights include the first dedicated Department of Defense mission; the first flight of Space Shuttle Orbiter "Discovery;" the first autoland; and the deployment of seven commercial communications satellites. A number of science and technology payloads will be flown, including the Large Format Camera and the Shuttle Imaging Radar. These missions will utilize all three of the delivered Space Shuttle Orbiters: Columbia, Challenger, and Discovery. Atlantis, the fourth orbiter, is scheduled for delivery toward the end of 1984.

In fiscal year 1985, the Space Transportation Operations budget provides for 11 Space Shuttle flights, including three dedicated Spacelab missions; completion of the TDRSS constellation of three orbiting spacecraft; the deployment of eight communications satellites; the first retrieval of a Shuttle-deployed spacecraft, the Long Duration Exposure Facility; transition from the conceptual phase of the McDonnell Douglas electrophoresis experimentation to small prototype production plants that will produce products in quantities to begin testing and marketing; and continued use of the Shuttle by the Department of Defense. The STS flight rate will continue to increase toward a rate of 24 per year by fiscal year 1989, when we expect to launch about 20 from KSC and the remainder from Vandenberg Air Force Base. The first flight from Vandenberg is planned for fiscal year 1986.

In order to make certain that the Space Shuttle can satisfy the performance requirements and timelines demanded in the future, the fiscal year 1985 proposed budget includes a program to enhance the performance of the Space Shuttle propulsion system. The major portion of this program is devoted to improving the Space Shuttle Main Engine system, first by increasing the reliability of the system and later by making substantial performance improvements through the incorporation of advanced technology components. This will be done by a combination of fine tuning of our designs on certain critical elements of the engine such as bearings and seals, and by taking longer-range steps to decrease operating temperatures and pressures under sustained flight at maximum throttle setting. Increases in the engine program are due both to this investment in improved durability and increased investment in spare engines and components. In addition to engine improvements, we are also taking steps to improve the performance of the Solid Rocket Boosters through the use of composite materials to make filament wound booster cases. Shuttle capability will also be enhanced by the continued NASA/Air Force development of the Shuttle/Centaur upper stage, which we will use to launch the Galileo and International Solar Polar missions in 1986.

In view of the successful performance of the Shuttle during the past year, I continue to believe that the investments we have made in the Space Shuttle system will pay off handsomely in the future. The Shuttle has become the Nation's primary

space launch system; because of this, we are continuing the program to produce the spare parts required to assure a launch capability that is so important in both the civil and the national security related sectors. We are also continuing the structural spares program; this will make it possible to assemble another orbiter should the decision be made to take this step. For these and many other activities in Space Transportation Systems, we are requesting $3166.0 million in fiscal year 1985.

Mr. Chairman, I would now like to turn to NASA's more traditional programs and provide you with a brief report of our accomplishments of the last year and also give you a synopsis of our plans for the future. In our Space Science and Applications program, the most important achievement was the successful launch of the Infrared Astronomical Satellite (IRAS), a cooperative project of the United States, the Netherlands and the United Kingdom. The mission was launched in January 1983, and remained operational through December 1983. A number of important discoveries have been announced, but in my opinion two are particularly outstanding. One is the discovery of about 20,000 new asteroids—about ten times as many as were previously known—with diameters between one and ten miles. This is a truly astonishing number and it is a result that was generally not expected by the astronomical community. Another equally important discovery of IRAS was that the star Vega is apparently surrounded by a dust cloud that is a prototype for the kind of planetary system that surrounds the Sun. This is the first positive evidence that there may be other stars in our galaxy that have planetary systems similar to those of the Sun. The large quantity of data that has been generated by the IRAS is now being analyzed. I am confident, Mr. Chairman, that equally significant discoveries will be made in the coming months as we look more carefully through the measurements that have been made by this satellite.

In our fiscal year 1985 budget request of $1371.5 million for Space Science and Applications, we are proposing several new important initiatives. One is the Upper Atmosphere Research Satellite, which is planned for launch in 1989, and will provide detailed measurements of the physical and chemical properties of the upper atmosphere. A particularly important aspect of the Upper Atmosphere Research Satellite program is that it will provide information about the molecular species in the upper atmosphere that determine the radiation transport properties in that arena. These properties, in turn, have a strong effect on the world's weather patterns, but perhaps more significantly on the long-term changes that may affect the eventual ability of the Earth to continue to support life. I believe that the Upper Atmosphere Research Satellite is the most significant new initiative in atmospheric science in many years, and I strongly recommend that you support the program.

Another new initiative is the Mars Geoscience/Climatology Orbiter planned for launch in 1990. The mission will be designed to obtain new geophysical and geochemical information about Mars, especially near the polar regions where not much data is available. This mission is the highest priority of a number of relatively low-cost missions referred to as "Planetary Observers," which were recommended by the Solar System Exploration Committee to provide a more intensive investigation of specific questions in planetary science. I believe the approach we are taking on this mission will be both an efficient and cost-effective method of planetary exploration.

For several years now, we have developed plans for a program to fly an Advanced Communications Technology Satellite called ACTS which is designed to develop advanced communications switching, processing, and antenna technologies; and to regain U.S. technological leadership in this important field. This program was designed to be executed in close collaboration with the communication satellite industry. It has been our purpose, consistent with the President's policy to encourage private sector commercial investments in space, to formulate our programs in such a way as to make it possible for private investors to take part in space activities. The ACTS program is an example of this policy. Recently, private companies have made proposals to build satellites with their own money which will do some of the things we had planned to do with the ACTS satellite. In view of this development, we have decided not to request funding to support a flight demonstration which had been planned in the ACTS project, but to continue the necessary related technology activities on the ground.

In addition to the new initiatives, the proposed fiscal year 1985 Space Science and Applications funding will continue to support a well-balanced and productive program in many areas of science. For example, the Hubble Space Telescope development activities will be continued, leading to a launch during the second half of 1986; the Galileo development activities will be continued, leading to a launch in 1986; and development will continue on the Venus Radar Mapper and the Gamma Ray Observatory, both of which are scheduled for 1988 launches. We will continue development of Spacelab instrumentation and other Shuttle payloads spanning an in-

creasing spectrum of research and development. The fiscal year 1985 budget also continues support for Life Science and Microgravity Science and Applications, as well as a strong and diverse supporting research effort which provides the foundation for the total NASA science and applications program.

NASA's fiscal year 1985 proposal of $9.5 million for Technology Utilization will allow continued effort to transfer NASA-developed technology to U.S. industry, the public and Government agencies, at a level made possible by the fiscal year 1984 Congressional augmentation.

NASA is requesting $342.4 million in fiscal year 1985 for Aeronautics Research and Technology to provide the technology advances critical to the continued preeminence of U.S. civil and military aviation. The planned program provides a solid base of fundamental research in the aeronautical disciplines—aerodynamics, materials and structures, propulsion, and controls and human factors—and systems research directed at the interactions among components and subsystems. Vehicle-specific areas of NASA research include subsonic aircraft, high performance supersonic cruise/maneuverable aircraft, and rotorcraft. Current activities are directed at improved performance, safety, and reduced costs of aircraft and operational systems.

Our fiscal year 1985 request continues important new initiatives begun in fiscal year 1984 in numerical aerodynamics simulation, advanced composite structures technology, and technology for the next generation of rotorcraft. In the Numerical Aerodynamic Simulation (NAS) program, the world's first Cray 2 high-speed processor will be delivered to Ames Research Center in December 1984 and installed in the NAS processing system network. The NAS system is expected to be initially operational in 1986 and fully operational in 1987, providing the U.S. aerodynamics community with an increased computational capability four to six times the current capabilities. The Advanced Composite Structures Technology (ACST) program is developing technology needed to incorporate composite primary wing and fuselage structures into large, transport-type aircraft by the 1990's. Full use of composites in primary airframe structures can potentialy reduce total aircraft weight by up to 15 percent, significantly lowering operational costs. The fiscal year 1985 effort directed at technology to increase speed for the next generation of rotorcraft consists of a joint NASA/Defense Advanced Research Projects Agency (DARPA) flight test program of the X-wing rotor concept utilizing NASA's Rotor Systems Research Aircraft.

During fiscal year 1985, the Advanced Turboprop (ATP) program activities will continue to develop the broad-based supporting technology required for advanced high-speed turboprop propulsion and will include advanced concepts and configurations such as counter-rotation propeller systems. These activities will be implemented in a manner that maintains the options to support a potential future systems integration/flight research phase to evaluate large-scale advanced turboprop structural, acoustic, and aerodynamic performance. Also during fiscal year 1985, the general aviation/commuter engine technology effort will continue to serve as a focus for small engine research that is aimed at 25 percent improvement in small engine fuel efficiency.

The fiscal year 1985 Space Research and Technology request of $150.0 million provides a broad base of long-term, high-risk, high-payoff technology essential to NASA's role of maintaining U.S. preeminence in space. This investment support Agency goals of improved operational effectiveness of the space transportation system and extended capabilities for U.S. science and applications missions. Further, it provides support to the technology needs of the expanding number of military and commercial space users. Of particular significance in this year's NASA program are advanced technology capabilities derived from ongoing research which will be focused in support of Space Station definition efforts.

NASA is requesting a total of $811.0 million for the Space Tracking and Data Systems program in fiscal year 1985. These funds will provide for the continuation of the vital tracking, command, telemetry, communications, and data processing support to meet the requirements for all NASA flight programs. Tracking and acquisition of data functions are presently accomplished through the use of a worldwide network of ground stations and by the first of a system of three Tracking and Data Relay Satellites.

This first TDRS was launched in April 1983, and was deployed into an elliptical orbit as a result of an anomaly during the second stage burn of the Air Force-provided Inertial Upper Stage (IUS). Through a series of orbital adjust maneuvers, utilizing the spacecraft's small thrusters, the TDRS-1 was boosted to a geosynchronous orbit.

In the past year, TDRS-1 has successfully supported Landsat-4, the STS-8 mission, the STS-9/Spacelabe-1 mission, and the STS-41B mission. The Spacelab mis-

sion received 99 percent of the requested mission data acquisition support. While we are still working with the USAF to resolve the IUS problem, we hope to launch the next TDRS in late 1984, with the third TDRS launch to follow in 1985.

NASA's fiscal year 1985 Construction of Facilities request of $160 million will provide for minimum essential facility needs, with particular emphasis on exploiting the Shuttle's capabilities, enhancing key research facilities for aeronautics and space technology development, and improving space communications capabilities. It includes provision for a new facility at the Ames Research Center to house the Numerical Aerodynamic Simulation (NAS) activities now under development, as well as funding to complete construction of two key facilities at the Kennedy Space Center—a solid rocket booster assembly and refurbishment facilitiy and a logistics facility to be used in conjunction with the Shuttle Processing activities. As part of NASA's Construction of Facilities request, we are requesting an increase in the funding limits for individual projects in the minor facilities program.

Mr. Chairman, I am very pleased to report that the NASA institution is fully prepared to support the President's budget initiatives. Perhaps the most important factor is that with the support of this Administration and the cooperation of the Congress, the decline in the civil service complement assigned to NASA has been stopped. For the past two years, the NASA Civil Service complement has been stable at approximately 22,000 positions and our fiscal year 1985 Research and Program Management budget request of $1331.0 million will allow us to continue with this number of people into the future. This stability has had the important consequence that in 1983 we were able to hire almost 600 recent science and engineering graduates. With the civil service complement we are proposing, we hope to be able to hire several hundred new science and engineering graduates next year as well. There is no doubt whatsoever that our ability to bring in so many new people will have a profound, positive influence on the future of NASA. The importance of this in-house capability has been well-recognized in many studies, including the recent one carried out by the Office of Science and Technology Policy under the chairmanship of Dr. David Packard. This study explicitly recognized the importance of healthy Federal laboratories to the economic health and national security of the U.S. and we endorse and support its recommendations.

An Agency-wide Productivity Improvement and Quality Enhancement Program emphasis last year is producing several long-term initiatives for streamlining our administrative processes, improving contract management, and enhancing support for science and mathematics education.

In addition to people, we must also look to the adequate operation and maintenance of our physical plant. Accordingly, NASA's fiscal year 1985 R&PM request includes an increase of $10 million to augment day-to-day recurring operational and preventive maintenance activities. I believe this is extremely important if we are to execute the programs that we have in mind.

CONCLUSION

Mr. Chairman, I have attempted to provide you and the Members of the Subcommittee with a short overview of the Administration's fiscal year 1985 program for NASA. I believe that it is an excellent program that will continue to ensure our Nation's leadership in space and aeronautics in the coming years. The program also provides a new vision for the future which is both realistic and farsighted. I would be remiss, Mr. Chairman, if I did not take this opportunity to thank this Subcommittee for its continued interest and support. Without your help and leadership over the past years, it would not have been possible for us to formulate the program that I am presenting today.

Mr. Chairman, I would now be pleased to answer any questions that you and other Members of the Subcommittee might have.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—BUDGET SUMMARY

[Dollars in millions]

	Fiscal year—		
	1983	1984	1985
Research and development:			
Space Station [1]	(4.0)	(14.0)	150.0
Space transportation capability development	415.5	431.7	361.4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—BUDGET SUMMARY—Continued

[Dollars in millions]

	Fiscal year—		
	1983	1984	1985
Physics and astronomy	470.3	567.6	677.2
Life sciences	55.7	58.0	63.3
Planetary exploration	186.4	217.4	286.9
Space applications	347.7	291.0	344.1
Space science and applications	1,061.0	1,134.0	1,371.5
Technology utilization	9.0	9.0	9.5
Aeronautical research and technology	280.0	302.3	342.4
Space research and technology	124.5	137.0	150.0
Tracking and data advanced systems	13.4	14.2	15.3
Total research and development	1,902.5	2,028.2	2,400.1
Space flight, control and data communications: [2]			
Shuttle production and operational capability	1,725.8	1,649.3	1,465.6
Space transportation operations	1,421.7	1,452.0	1,339.0
Space and ground network, communications and data systems	485.5	674.0	795.7
Total space flight, control and data communications	3,633.0	3,775.3	3,600.3
Construction of facilities	103.5	155.5	160.0
Research and program management	1,197.4	[3] 1,258.5	1,331.0
Total	6,836.4	7,217.5	7,491.4
Outlays	6,663.9	7,068.2	7,370.0

[1] In fiscal year 1983, the Space Station Activity was included in Space Transportation Capability Development. In fiscal year 1984, $6.0 million was included in Space Transportation Capability Development, $2.0 million in Space Science and Applications and $6.0 million in Space Research and Technology.

[2] Prior to fiscal year 1984, these programs were included in the Research and Development appropriation.

[3] Includes $20.0 million for proposed pay raise supplemental.

[The following information was subsequently received for the record:]

Questions of Senator Gorton and the Answers Thereto

SPACE STATION

Question 1. It has been reported that West Germany and Italy have proposed European development of a Space Station facility, called Columbus. This development would lead to a 1999 launch of a manned free-flying laboratory.

What effect would a development of this nature have on the financial participation of foreign countries in a U.S. Space Station development?

Answer 1. The Columbus initiative currently under discussion by West Germany and Italy is understood to be a pressurized Space Station laboratory module based upon Spacelab derived hardware. Current development plans foresee availability of the module in the early 1990's consistent with the initial operational capability planned for the U.S. Space Station. In this context, it is not regarded as a competitive foreign endeavor but, rather, one of many candidates for possible international cooperation in the U.S. program.

Question 2. What are the essential technologies that have yet to be developed for a manned Space Station, which are the "pausing" technologies?

Answer 2. There are no essential or high risk technologies under consideration for the initial Space Station which have yet to be developed or could not be available for the planned development program. The objective of the Space Station advanced development program is to develop and demonstrate new high leverage technologies to a schedule that will take the risk out of the hardware development phase. Over forty percent of the planned FY 1985 budget is for developing the technologies we believe are necessary to provide us with a Space Station with improved efficiency and effectiveness. Work has been planned to focus these technologies to a Space Station application, building, and integrating prototype components into subsystems for demonstration of promising technology options in ground-based test bed facilities,

and conducting flight experiments utilizing the Space Shuttle. A list of the candidate technologies for further development follows:

By Technology Discipline:

Power: High Capacity Energy Storage; Improved Performance Solar Arrays; Fuel Cell Electrolysis; Automated Power Subsystems; High Voltage/Power Components; and Bulk Power Transfer.

Environmental Control and Life Support: Extravehicular Activity—Suit, Mobility Aids, Tools; Crew and Work Station Accommodations; and Regenerable Life Support System.

Auxiliary Propulsion: Low Thrust Gaseous Hydrogen/Oxygen Auxiliary Propulsion System Components; Cryogenic Fluid Resupply; Cryogenic Fluid Management; and Electrothermal Thruster System.

Data Management: High Speed/Capacity Data Systems; Fault Tolerant Systems; Bubble Memory Systems; Adaptive Data Networking; and Software Management.

Structures/Mechanisms: Advanced Materials for Active/Passive Damping, Coatings, and Films; Rendezvous, Docking, Berthing Systems; Advanced Mechanisms; Structural Concepts, Dynamics and Analysis for large Arrays, Solar Arrays.

Thermal: Integrated Thermal Utility/Thermal Bus; Maintainable/Replaceable Radiator; Long Life Heat Rejection; and Versatile Thermal Acquisition and Transport.

Human Capabilities: Habitability Requirements for Extra-vehicular and Intravehicular Activity (EVA and IVA); Man/Machine function Allocations; Human Interface to Inteligent Systems; Direct, Supervisory and Automatic Control of Teleoperators and Robotics Orbital Maintenance Methodology; and Medical Aspects.

Attitude Control and Stabilization: Predictive Methods for Large Spacecraft Response; Integrated Analysis Methods; Advanced Guidance and Control Components; and Large Momentum Management Devices.

Communications: Multiple Use Antennas; Infrared Communication Systems; Accurate Ranging and Tracking Systems; 60 Gigahertz Devices/Components; and Vehicle-to-Vehicle and Vehicle-to-Station Communication Systems.

Systems/Operations: Autonomous Systems; Hierarchical Control; Self Diagnosis/Repair; Integrated Crew and Life Support/Energy Management System Development; and Attitude Control/Energy/Crew and Life Support System Development.

Question 3. How and to what extent does NASA intent to implement automated systems, robotics, or telepresence on a manned Space Station? How much of this technology has yet to be developed?

Answer 3. NASA's intent is to develop a Space Station that will operate in an optimally effective manner. The Space Station, while it will be permanently manned, will not be able to fulfill the multiplicity of functions envisioned unless a plan is developed to optimally partition functions between man and automated elements. NASA plans to sustain the technology of robotics and expert systems to effect the automation and telepresence required on the Space Station. Telepresence capabilities will be necessary to service satellites that are in orbits not available to either the Space Shuttle or the Space Station. While the industrial community has developed the technology whereby deterministic functions, such as the process of welding automobiles, can be performed by the use of programmed robots, to date functions that cannot be defined in detail (stochastic processes) cannot be fully automated. A number of functions foreseen for the Space Station fall into this latter category. Development of the technologies of expert systems and artificial intelligence will no doubt lead to expanded automation capabilities in the 21st Century.

These technologies will be supported and advanced through the development of the Space Station.

Question 4. What impact would the annual Space Station maintenance and mission requirements have on the flight schedule of the Space Shuttle fleet?

Answer 4. As currently conceptualized, one dedicated STS flight will be required in the beginning to provide for assembly and checkout of the station. Additional flights to assemble the remainder of the Space Station need not be dedicated but can be co-manifested with other planned flights. The resupply, nominally on 90-day intervals, can be co-manifested with other flights to the same vicinity. Since the Space Station will be in a 28.5 degree orbit, many flights will be scheduled to that proximity and co-manifesting will be facilitated. Overall, impact to the Space Transportation System will be minimal.

Question 5. What consideration has been given to developing a manned Space Station that has docking and communication technologies that are compatible with those of the Soviet Space Station?

Answer 5. One of the primary planning guidelines for the Space Station program has been the requirement for "clean interfaces" between the modular elements of the overall system in order to minimize the complexities of element integration and

to optimize the use of common subsystems as well as the potential for participation by elements contributed by the commercial sector and foreign entities. Planning, however, has not included compatibility with the Salyut class docking mechanisms which are based on current or older technology. U.S. Space Station communications technology will be based upon the capabilities of the Tracking and Data Relay Satellite.

EXPENDABLE LAUNCH VEHICLE (ELV'S)

Question 6. The Air Force has announced that it intends to purchase and launch a minimum of two commercial ELV's per year during FY 1988-1992.

Further, the Air Force has said that one reason that it will probably not select a Shuttle derived launch vehicle for that period is that this vehicle could not be developed by the 1988 period required. When could a Shuttle derived launch vehicle be available?

Does NASA have a preference as to what kind of backup capability the Air Force might eventually use?

Answer 6. Marshall Space Flight Center (MSFC) has proposed a schedule for the SRBX which is under Headquarters review at present. An Agency position should be available by May 1.

We believe there would be numerous advantages to use of a relatively simple Shuttle derived vehicle referred to as SRBX. This tradeoff is now being examined by the National Academy of Engineering at Congressional request.

Question 7. NASA has entered into negotiations with Transpace Carriers and with General Dynamics to commercially produce the Delta and Atlas/Centaur ELV's respectively.

Could you tell us the current state of these negotiations?

How and to what extent has this potential commerical ELV capability affected NASA's market projections concerning the need for a fifth orbiter?

Answer 7. The current status of actions taken consist of the General Dynamics Convair (GDC) being selected for operation of the Atlas Centaur program and information is being exchanged between NASA and GDC prior to negotiations. A draft agreement has been forwarded to GDC, and a response with initial negotiations is anticipated in early March 1984.

We have notified Transpace Carrier, Inc. (TCI) of our willingness to negotiate with TCI leading to a commericialization agreement for the Delta vehicle system. Information has been exchanged with TCI and negotiations have begun.

NASA is being responsive to the President's directive, including participation and coordination with the Department of Transportation (DOT), selected as the lead agency within the U.S. Government to serve as the focal point for all inquiries and activities relative to seeking U.S. Government approval for commercial ELV activities.

For the near term, we have not seen any impact on NASA's STS Marketing projections or the need for a fifth orbiter with the advent of a potential commercial ELV capability.

SCHUTTLE DERIVED LAUNCH VEHICLE

Question 8. Could you comment on NASA's plans or studies to develop a Shuttle-derived launch vehicle, using the Shuttle's external tank, or the solid rocket boosters, or the main engines, or some combination thereof?

Answer 8. NASA has performed studies of this subject both in-house and by contract, for the past decade. Additional studies are planned. Payload capability for the most interesting ones ranges from Shuttle-class up to three times the weight and four times the volume; still greater performance could be obtained. The smallest and simplest of these vehicles is identified as SRBX; it used the solid rockets boosters but not the external tank or main engines. The larger ones use all three elements in various configurations and with varying degrees of recovery/reuse.

Question 9. How much would it cost to build the various classes of Shuttle-derived launch vehicles, and under what circumstances would these launch vehicles be most useful?

Answer 9. Cost of these vehicles is undergoing review in connection with a broad survey by the National Academy of Engineering as requested by Senator Garn and Congressman Boland. We expect to have supportable figures in the next two months.

The SRBX (see answer 8 above) would be an important option to consider if the Nation requires an unmanned complement to the Shuttle for selected missions, because SRBX could be available sooner than other Shuttle-derived vehicles and it has

performance substantially the same as the Shuttle. One of the larger capacity vehicles will be considered as a tanker for transporting upper-stage propellants to the Space Station. Other potential uses for the larger vehicles are still under investigation.

INCORRECT DEPLOYMENT OF SATELLITES

Question 10. On the last Space Shuttle mission, two communications satellites were deployed into incorrect orbits due to malfunctioning upper stages.

Could you tell us the status of your investigation these two mishaps?

What precautions might NASA have taken prior to the deployment to detect the defect in the upper stage engine nozzles?

What effect, if any, will these mishaps have on future Shuttle missions?

What consideration has NASA given to retrieving and repairing these satellites and what are the controlling factors in making this decisons?

Answer 10. McDonnell Douglas Corporation (MDC), the producer of the PAM stage, and Thiokol, the motor manufactures, are conducting the failure investigation with assistance from NASA as requested. The investigation is now underway with findings to be announced later.

McDonnell Douglas Corporation (MDC) and Thiokol examined all manufacturing assembly and handling information available prior to the second deployment and were unable to find evidence for not deploying.

The impact on future Shuttle missions cannot be determined until after the failure investigation is complete and PAM customers assess the resulting situation.

The satellite owners must make decisions regarding retrieval and/or repair. Such decisions involve business matters into which NASA, has no insight. NASA could conduct engineering analysis to determine the engineering feasibility should the owners so desire. There are questions to be resolved: "Can spacecraft be grappled and reattached physically to the orbiter? Can the spacecraft be saved? Who will pay for the effort?"

FIFTH ORBITER

Question 11. You have said that, except for an attrition vehicle, you do not see the market demand for a fifth orbiter at this time?

How far into the future are your market projections?

Our National Space policy states that the Space Shuttle is our primary space launch vehicle. Given this posture, could you comment on whether or not we need an attrition vehicle for our Nation's primary space launch system.

Further, you have said that there is a window over the next two to three years during which NASA has to decide if it will develop a fifth orbiter. How much would a fifth orbiter cost if the decision to procure were made in fiscal year 1985? Fiscal year 1986? Fiscal year 1987?

Answer 11. Projections are and have been made out to the early 1990's. However, the confidence in the projections lessens as one projects further into the future. Projections that go out three years are firm because the customers have started progress payments or funding of Government projects are in Agency budgets. Commercial and foreign customers normally start serious negotiations four years before launch. Projections beyond this period of time are subect to changes in business plans, etc. Therefore, projections out to when the fifth orbiter would be delivered are anticipated and subject to the customer's business plans, competition, etc. It is difficult in this early stage of Shuttle to make accurate projections out into the next decade.

NASA has continued to study the need for additional Space Shuttle orbiters. These examinations have focused upon impacts of the loss or extended downtime of one of the currently authorized four orbiter fleet and on the likelihood of future traffic growth beyond current capability. These studies have indicated that the current fleet may be sufficient for the remainder of this decade. However, concern was expressed on the need for assurance to accommodate unscheduled maintenance or accidents causing extensive damage or loss of an orbiter.

For this reason, an orbiter structural spares program was initiated in fiscal year 1984. This program provides additional assurance in maintaining Shuttle operations and also protects orbiter production capability through fiscal year 1985. This program along with the operational spares program, in our judgment, represents the optimal approach to retention of the planned orbiter fleet and the option to proceed with full production of an additional orbiter at a later date. This issue will be reviewed again as part of the fiscal year 1986 budget formulation process.

Costs for procurement of a fifth orbiter are estimated as follows:

Fiscal year:	*Billion*
1985 start—Mid 1989 delivery	$1.95
1986 start—Mid 1990 delivery	2.2
1987 start—Mid 1991 delivery	2.4

It should be noted that the cost estimates include the $420 million which will be expended through fiscal year 1987 for the structural spares program. In addition, there is considerable uncertainty over the validity of the fiscal year 1987 start estimate due to the substantially greater loss of subcontractor production capability than would be the case of an fiscal year 1986 start.

EXTENDED DURATION ORBITER

Question 12. In your testimony before this Subcommittee in November, you said that NASA is studying the concept of modifying an orbiter to extend its on-orbit time to 20 days.

How much would it cost and how long would it take to develop this 20-day capability?

How might a 20-day extended duration orbiter serve as a test-base for future Space Station systems?

How and to what extent would Space Science and Space Applications experiments be enhanced by the ability to stay in orbit aboard the Shuttle for 20 days?

Answer 12. We estimate it would cost approximately $100 million to $250 million and take about thirty to thirty-six months to develop.

An orbiter with an extended duration stay time of 20-days would not enable any additional Space Station flight experiments beyond those presently foreseen for the Shuttle. It would, however, enhance currently foreseen Space Station flight experiments by minimizing the effects of start-up transients, allowing more such experiments to be performed per mission, and by relieving the impact of tight mission timelines and allowing more time for manned interactions such as adjustments and repairs.

We have for a number of years looked at the potential need for an extended duration orbiter and have identified three areas in which an expanded capability could be useful: (1) Vapor Solution Crystal Work; (2) Complete Solar Track-Entire Pass; and (3) Full Earth Coverage, Polar Orbit.

Our analysis to date indicates that it would be very difficult to justify the major expenditure of funds, control and avionics changes which would be necessary to extend the duration beyond 20 days with no identified critical requirements for that time which could not be met more effectively by the space station.

ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)

Question. 13. It is my understanding that NASA has decided to forego a flight-test program for its ACTS program in lieu of a ground-test program based on the fact that Hughes Aircraft Company has announced that it will deploy two communications satellites in the Ka band, the same band frequency for which ACTS was designed.

What technological questions would be unresolved by foregoing a flight-test program in lieu of the ground-test program and would this be worth the cost savings?

What is the current funding profile for ACTS for fiscal year 1986 and the future?

Answer 13. The primary unanswered questions would be associated with the electronically hopped spot beams. The performance of these beams in a real environment cannot be simulated.

Another primary unanswered question would be associated with the system implementation of a network. There are several concepts to acquire and stabilize all of the stations operating in the Satellite Switched Time Division Multiple Access beam hopping network. It is not possible to simulate these systems to the satisfaction of the users.

There are several secondary questions that are associated with component reliability and ground terminal development.

In our judgment, the additional cost of a flight test to answer these questions is not warranted.

There is currently no funding allocated for ACTS for fiscal year 1986 and beyond. The Agency is still developing a ground based program that would require in the range of $20–25M per year in future years.

Question. 14. How, and to what extent would you expect market-oriented, profit driven communications companies to make the dramatic technological break-

throughs needed to maintain our world leadership position in communications technologies?

Answer 14. Industry, as evidenced by the recent FCC filing, is pursuing the near-term needs of the communications market; NASA will pursue technology development and ground testing for future communications satellites. Therefore, it is our belief that industry and the U.S. Government jointly can keep the United States competitive with other countries in communications technologies.

Question 15. When Hughes announced its plan to develop its two satellites for the K-band frequency, the funding for ACTS was reduced from $95 million for a flight-test program to $5 million for a ground-test program. What has followed has been a widespread show of support by the vendors and users within the communications industry for an ACTS flight-test program. Can you explain why the industry is so supportive of an ACTS flight-test program even with the announcement of the Hughes Ka band proposal?

Answer 15. This question might be more appropriately directed to the industry firms who will have to make their own business decisions about investing in advanced satellite technologies.

SPACE SCIENCE

Question 16. The findings of the NASA-sponsored NASA/University Relations Study Group indicated that science laboratory equipment and instrumentation at our university laboratories is aging and becoming obsolete. What has been done or is being done by NASA to correct this problem?

Answer 16. The NASA University Relations Study Group recommended $10 million annually for equipment grants. The fiscal year 1985 budget request includes an estimated $250–260 million which will go to educational institutions. We estimate that approximately 10 percent of these funds will be used specifically for instrumentation; however, we do not budget specifically for equipment, but rather for the research. We believe we are working to achieve the objectives of the study.

Question 17. The Committee welcomes the new start of the Mars Geoscience/Climateology Orbiter in the budget request. However, it has been noted that there is no line item for Planetary Observers.

Does the absence of a Planetary Observer line item indicate a lack of commitment by NASA to the low-to-moderate cost inner solar system missions?

If not, do you expect that the Planetary Observer line item will appear in the fiscal year 1986 NASA budget request?

Answer 17. The presence of the first Planetary Observer, the Mars Geoscience Climatology Observer (MGCO), in the budget request does indeed indicate NASA's commitment to low-to-moderate cost inner solar system missions. The demonstration of the viability of the Observer program concept will be provided by the Mars Observer project and the decision on the program concept will then be made.

Assuming the experience with MGCO is positive, we plan to request approval for the Planetary Observer line in one or two years time.

Question 18. Out of 29 U.S. Principal Investigator (PI)-class instruments selected in 1978 as Space Shuttle payloads, only three have been funded for development and thirteen more for definition studies, while thirteen have not been funded at all. There is some concern that this reflects a lack of commitment by NASA toward building and maintaining a strong space science research effort.

Could you comment on NASA's support for space science research in the context of these PI-class experiments?

Answer 18. In addition to the three instruments currently under development for the Astro payload, development will begin in fiscal year 1984 on three additional instruments, a high energy astrophysics instrument for OSS–2 and two plasma physics instruments for Space Plasma Lab. We are currently reviewing the remaining instruments selected under the Announcement of Opportunity to determine whether the proposals are still current in terms of technology and determine which of the remaining instruments will begin development in fiscal year 1985. As a minimum, one high energy experiment will be started, and hopefully additional plasma physics experimentation. Future plans call for possible incorporation of additional solar physics experimentation on either the second and subsequent flights of the Solar Optical Telescope or flights of the Sunlab, which consists of reflight of the Spacelab 2 solar physics pallet. We intend to begin development on all remaining instruments in the fiscal year 1986/1987 time frame.

Question 19. For fiscal year 1984, $12 million was removed from the Solar Optical Telescope (SOT) funding to assist the Space Telescope cost overruns and develop-

ment problems. In the proposed fiscal year 1985 budget, there is again funding for some definition work on SOT, but not enough for full-scale development.

When do you expect that SOT will receive a new start status?

Likewise, could you tell us when NASA plans to move ahead with a full-scale development on the Shuttle Infrared Telescope Facility (SIRTF) and on the Advanced X-ray Astrophysics Facility (AXAF)?

Answer 19. The decison to hold the Solar Optical Telescope (SOT) in an advanced definition phase was made last year, primarily as a result of the management difficulties experienced at Perkin-Elmer on the Space Telescope (ST) program.

We plan to move forward with SOT in an orderly fashion. NASA established an independent ad hoc working group of senior technical managers and scientists to review the SOT program technical and function approach. That group took no exception with the planned approach. Some useful suggestions regarding objectives were made and are being incorporated into the program. Assuming continued progress on the Space Telescope, we will be in a position later this year to determine exactly what activities will be undertaken on SOT in fiscal year 1985, i.e., continued advanced definition or design/development activity initiation.

The IRAS mission established the need for long-duration observations with a telescope. IRAS also demonstrated the management of superfluid helium in zero g and long-lived dewar technology. Infrared detector technology is also maturing and approaching photon counting capability and limitations, so that instrument detector changes may not be needed as frequently as originally thought. Therefore, we are examining three options on implementing SIRTF. These include (1) developing the facility as a Shuttle payload, (2) proceeding directly to a long-lived mission which may be a free flyer or (3) part of a platform associated with the Space Station. When adequate study of the options with the scientific community has been completed, we will make a decision as to the appropriate implementation mode. It is our current assessment that fiscal year 1987 is the earliest that NASA would be in a position to propose SIRTF as a new initiative.

The Advanced X-Ray Astronomical Facility remains among the agency's highest priority new missions. Phase B contractors will be selected within the next few months. These studies will be conducted over a period of approximately two years. Therefore, the earliest that NASA would be in a position to propose AXAF as a new start is fiscal year 1987.

Question 20. What work is NASA performing in the field of hypersonic aircraft technologies that would permit an aircraft to achieve velocities far greater than Mach 1 while traveling within the atmosphere much like a conventional airplane does?

What are the uses for such an aircraft and should we be pursuing these technologies more vigorously?

Answer 20. NASA's hypersonic technology program includes aerodynamic, propulsion, structures/materials, and configuration synthesis disciplines. The key to fruition of this technology is the development of turbo-ramjets/scramjets and their integration into viable vehicle configurations. The turbo-ramjet would power an airplane from take-off up to Mach 6 cruise at 100,000 ft. altitude. Liquid methane or hydrogen fuel is required to cool the propulsion system which translates to a large, though relatively lightweight, titanium structured vehicle. The scramjet (supersonic combustion ramjet) becomes more effective than the ramjet at Mach 6 and beyond; these engines could be operated at speeds in excess of Mach 10. Hydrogen-burning, regeneratively-cooled scramjets are being examined for use with transatmospheric vehicles.

Civil transports and space-plane boosters are the primary roles NASA is projecting for hypersonic aircraft. The fast reaction, high altitude, and wide area coverage characteristics of such aircraft also have appeal for interceptor, penetrator, and reconnoiter scenarios. NASA's hypersonic airplane effort is sufficient to maintain growth in an embryonic technology. Eventually, when the technology at the laboratory scale is more mature, flight testing of these concepts would be required.

Question 21. The world market share of the European airbus has grown from only three percent in 1975 to more than 20 percent.

Is this a trend that is likely to continue for the next several years?

What has enabled our foreign competition to increase so dramatically its share of the world market.

What should the Federal Government and NASA do to reverse this trend?

Answer 21. Whether or not the trend continues over the next several years will probably depend on the competition for the 120–150 passenger transport which is generally regarded as the next major segment of the world air transport market. These new transports would replace the two-engine and three-engine narrow bodied

transports now in service, and also permit additional growth of the airline fleets. The replacement market alone is projected at more than $60 billion in 1983 dollars.

Airbus, Boeing, and McDonnell Douglas are all working on new designs for this market, and the U.S. companies are also offering derivatives of existing transports. It is premature to predict the outcome of this competition, but if the European governments' commitment to the Airbus A-320 development support is maintained, the Airbus must be rated as a strong contender.

The Airbus success can be attributed to: the development, with strong government support, of a technically competitive airplane which filled a market need; aggressive marketing—also with government support, and directed largely at the foreign airlines which represent the most rapidly growing component of the world market; and, the ability to operate at the low production rates compatible with a slowly developing market.

Apart from the economic measures which are beyond NASA's purview, we believe the government and NASA should maintain and continue to strengthen support for aeronautical research and technology, as proposed in the 1985 request. This approach enables U.S. industry, as well as DOD, to undertake promising new developments utilizing the most appropriate advanced technology with confidence and affordable risk.

Question 22. The second and third satellites in the Tracking and Data Relay Satellite System are scheduled for launch in 1984 and 1985, respectively.

How confident are you that the IUS will be certified soon enough to launch the second TDRS satellite in 1984?

Has any consideration been given to launching TDRS b and C using an upper stage different from the IUS, and if not, how long can we afford a less than fully operational TDRS system?

When do you expect a 3-satellite TDRS system to be fully opertional?

To what extent would any of the future Shuttle missions be compromised if the TDRS system is not fully operational by this date?

Answer 22. The control anomaly encountered by the second stage of the IUS during launch of TDRS-A has been extensively investigated by an Air Force/NASA/Industry team. The cause of the anomaly has been identified and corrective design changes are being implemented. This has been a lengthy, painstaking process which we believe will result in a fuly operable upper stage. The current projection of the IUS ready-to-launch capability is late-November 1984 in sufficient time to meet the scheduled launch of TDRS-B now planned for March 1985.

There are no existing upper stage alternatives to IUS that have the performance capability to put the 5000 pound TDRS into geosynchronous orbit. An assessment was made of IUS motor substitutions and new vehicle developments for launching the TDRS spacecraft. Considerations of risk, schedule and costs have indicated that the most reasonable solution, and the one we have followed, is to fix the IUS.

NASA is most anxious to achieve a fully operational TDRSS,. However, with the single spacecraft now operating in orbit we feel we can provide (although with some compromise) essential and critical support to users requiring service between now and the time the second spacecraft (and later a spare) become operational. This will of course necessitate extending ground network operations beyond the date anticipated for closing the major portion of the earth orbital tracking stations. It is estimated that the costs of extend network operations and to accommodate the delay of the TDRSS are now on the order of $5-6M per month.

Based on the latest USAF schedules for IUS availability, the earliest would be the Fall of 1985. The budget was formulated assuming November 1984, and February 1985 for the second and third launches, reaching full operational status in March/April 1985.

There will be no impact to Shuttle delivery missions. For some attached payload missions, some compromises may be necessary in the volume and period of time data is acquired, but this reduction will still provide for a viable mission in each case.

Question 23. Prior to the launch of the STS-9 Spacelab mission, it was revealed that the forward K-bank capabilities of TDRS-A had experienced serious degradation?

Has this problem been resolved and if not, when will it be resolved?

Will any future missions be compromised by this degraded capability?

Answer 23. Investigation has revealed two separate K-bank problems. One is a failure in a diplexer which feeds the single access antenna; the other is a traveling wave tubed amplifer (TWTA) failure. The diplexer failure has been traced to contamination and modifications are in process to prevent recurrence. We have had one TWTA fail in ground testing in addition to those that have failed in orbit. The

suspected cause of the failures is arcing in the high voltage power supply. Investigation is continuing to isolate the failure mode. At this time we have no reason to believe that we will not be able to isolate this problem.

There is no reason to believe that future missions will be compromised by the degraded capability of TDRS–1 K-band forward link. Additional satellites will be launched and operational prior to the time when TDRSS user mission loading would required full system capabilities.

COMMERCIALIZATION

Question 24. It is well understood that NASA is trying to develop greater participation by the private sector in space activities such as manufacturing in zero-gravity. It is also well understood that the private sector is very reliant on NASA's Materials Processing in Space activities; yet funding for Materials Processing in Space actually decreased from the FY 1984 level.

How can we expect to develop this partnership between the private sector and the Government is we do not adequately support those high-risk, long-term activities, such as Materials Processing in Space, that are so critical to the entry of private firms into the arena of space commercialization?

Answer 24. Materials processing is only one of the things for which we allocate resources. NASA plans its research on the basis on both near- and far-term requirements including consideration of the opportunities for the industrial and research communities to pursue commercial ventures in space.

Question 25. I understand that NASA is transitioning its Space Commercialization Task Force into a permanent office in NASA Headquarters. What is the status of this move, at what level within the Agency will this office function, and what substantial results can we expect to see from this initiative?

How much is there in the FY 1985 budget request to support this commercialization initiative in NASA Headquarters?

Answer 25; It is in the final stages of decision as to where and at what time. As we see it today, the responsibilities of the office within NASA would probably include:

Policy development and maintenance, including identification of barriers to commercialization and their proposed solution.

Development of the commercialization program inplementation plan.

Program evaluation for the Administrator.

"Leadership"—Monitoring, coordination, direction, authority to resolve disputes.

There is no money set aside for this effort at this time.

Question 26. The following three questions refer to the $20.4 million award to General Electric Company for a feasibility assessment of the gearless counter-rotating propfan engine concept.

What preparatory work was done to justify a demonstration program of this scope and magnitude?

What comparative studies were performed to assess the relative merits of the gearless counter-rotating propfan concept versus the single rotating propfan concept?

Will the results and data of the work be proprietary, and, if so, what justification is their in classifying this as proprietary when public funds will be used?

Answer 26. The majority of the preparatory work has been done by the General Electric Company. Prior to submittal of their unsolicited proposal for the proof-of-concept testing of the Unducted Fan (UDF) propulsion system, GE conducted extensive proprietary design studies supported by domestic airframers. These studies confirmed that counter-rotation would provide approximately 8 percent higher efficiency and that it was possible to eliminate the complexity of the gearbox with little cycle penalty. In addition, the airframer studies showed that a pusher type propeller with rear fuselage mount was attractive in isolating the noise and vibration from passengers. Overall the potential fuel savings of the UDF concept compared to advanced turbofans is 20–30 percent. This would be a significant breakthrough.

Prior to the award of the contract to GE, NASA held a "peer review" of the counter-rotating UDF concept. The peer review committee consisted of three domestic airframers, key university specialists, a propulsion industry representative, as well as Air Force and Army propulsion experts. The committee unanimously recommended that the proof-of-concept program be pursued. Pertinent conclusions from their final report are cited below:

"Turboprop technology is one of the few concepts that in today's capital sensitive environment offers sufficient operating improvement to justify aggressive pursuit. The Unducted Fan (UDF) design concept provides an alternative to the geared pro-

peller approach. This alternative is particularly applicable to high altitude and cruise speeds associated with modern transport aircraft. In addition, the UDF has the inherent capability of being scaled to higher power levels where the geared propfan approach will need considerable additional development to advance from a 13,000 shaft horsepower (SHP) to 20,000 plus SHP."

"The UDF concept needs to be brought to a level of technical readiness, before new aircraft programs can give this approach serious consideration. This can only be achieved through a large scale proof-of-concept test of the integrated propulsion system."

"The peer review group recommends that the proof-of-concept program be pursued in the 20,000 horsepower size, because the major advantages of the concept appear to lie in the application to larger size engines and propellers. The group believes the UDF concept is a viable alternative to the development of reliable, flight-weight gearboxes at this lower level."

Finally, the NASA ATP program is a broad-based effort to develop single- and counter-rotation propeller, related drive systems and aircraft technologies for a new generation of fuel efficient aircraft. It is appropriate that the UDF and its associated model test program be included. This model test program, which will evaluate the aerodynamic and acoustic performance of the counter-rotating blades, will begin testing FY 1984.

NASA and the engine companies have conducted numerous studies of counter- vs. single-rotation propeller systems. These consistently show approximately an 8 percent fuel savings for counter-rotation. Proprietary GE studies show that the gearless UDF concept provides essentially the same weight and fuel savings benefits of a gear-driven counter-rotation propeller system. This has been confirmed by a preliminary NASA review. The UDF eliminates the complexity and cost of a gearbox and is readily scalable to large sizes without requiring a high-power gearbox development. In addition, the VDF is an aft mounted usher configuration with potentially lower cabin noise and vibration, and absence of propeller slip stream/wing interaction.

No, the results and data will not be proprietary. Inasmuch as public fund are involved, all technical results will be in the public domain. However, these results will be afforded protection from foreign dissemination by the NASA For Early Domestic Dissemination (FEDD) requirements and procedures.

QUESTIONS OF SENATOR TRIBLE AND THE ANSWERS THERETO

Question 1. On Friday, February 24, 1984, President Reagan signed an Executive Order designating the Department of Transportation as the lead agency for expendable launch vehicle commercialization. What is NASA's view on the mission of DOT's new Office of Commercial Space Transportation, and how will DOT's role in this area be related to what NASA will be doing to encourage space commercialization?

Answer. NASA participated in the preparation and review process of the Executive Order signed by the President on February 24, 1984. NASA will provide support to the Department of Transportation (DOT) in its role as lead agency for commercial expendable launch vehicles. We view the roles of the two agencies as complementary in meeting the national objective of encouraging private sector investment and involvement in space activities with the DOT focus being on expendable launching systems and the NASA focus continuing in the other more traditional NASA areas. We expect that both agencies will work closely together in achieving the same objective.

Question 2. NASA has requested $150 million in fiscal year 1985 for Space Station funding. I understand that NASA's original request to OMB was for $235 million. How will the decrease from the originally proposed Space Station funding impact putting a Space Station in orbit by the early 1990's? With slightly increased R&D funding, can we get it up earlier? Please provide figures for the record on how much will be required to establish a Space Station capability one year earlier, two years earlier, etc.

Answer. Since the Space Station definition funding is still being planned at a level of approximately $700 million (real year dollars) over a three year period, and since the development funding profile approximates our current projections, the $85 million reduction did not result in a major impact to the proposed early 1990's date for initial operational capability. A slight increase in funding would improve our ability to meet that date. Since we are at an early stage of the program, it is very difficult to quantify the funding requirements for a Space Station capability one or two years earlier than the stated target schedule. Moreover, it would be difficult to

accomplish the needed technology advances and the development work in an accelerated manner without increasing the development schedule risk.

Question 3. The Subcommittee on Science, Technology and Space will soon hold hearings on the Advanced Communications Satellite program. NASA recently decided to drop the flight element of this program and continue ground-based research. Why did NASA decide to stop supporting the flight testing of this communications technology in light of the advances being made in this area by our competitors abroad? Will NASA's decision not to support ACTS flight program have a negative impact on U.S. leadership in communications technology?

Answer. The ACTS program has been restructured to exclude the flight test, but technology development required for future communications satellites will be continued through ground testing. The ground test program will allow many of the original ACTS program goals to be accomplished. Hardware will be developed for the critical technology elements which will further reduce the risks associated with placing any ACTS type flight system into orbit. More specifically the program will prove the capability of the multibeam antenna, the baseband processor and the Intermediate Frequency (IF) switch matrix to perform in a communication system. A complete end-to-end communications system test will be conducted to verify that the advanced system synchronization and use access is feasible. Finally, the ground test program will provide a first estimate of the communications quality, reliability and availability.

The decision to restructure the ACTS program was made only after the private sector expressed their intent through a filing with the Federal Communications Commission to develop a communications satellite in the 30/20 GHz range to accommodate U.S. near-term requirements. NASA will continue to concentrate on development of technology required for future communications satellites. Therefore, it is our belief that the United States can maintain a sharp competitiveness with other countries through the currently planned joint efforts of Government/industry.

Question 4: An NASA Space Commercialization Task Force recently submitted for NASA senior management review a NASA space commercialization policy. Contained with the Task Force policy statement was the recommendation that NASA establish, at a high level, an Office of Space Commercialization. When will NASA complete its review of the proposed commercialization policy and establish a high level space commercialization office?

Answer. The organizational location of the office is under final review. There are a number of items in the budget that deal directly with the commercialization of space: materials processing, support of ELV's reduced rate launches, and engineering support of a number of Memorandum of Understandings (MOU's) and Joint Endeavor Agreements (JEA's). It is anticipated that the new office will be established and a specific set of commercialization requirements be developed for 1986.

Question 5: How will the Langley Research Center be supporting the two-year Space Station definition effort, and what will be the eventual role of Langley once the Space Station becomes operational?

Answer. A key activity of Space Station definition activity is the Advanced Development Program. The prime objection of this program is to develop and demonstrate new high-leverage technologies which will optimize the Space Station's functional characteristics in terms of performance, cost, and utilization. Currently, the Langley Research Center (LaRC) is involved in developing new technologies which have been identified as having high potential for use in the Space Station. LaRC involvement in these technology development activities, primarily in material/structures and data systems, will continue through the definition phase of the program.

In addition to developing new technology, consistent with its expertise, LaRC is expected to play a key role in extended definition of possible evolutionary requirements. In this role, LaRC will continually assess possible evolutionary requirements of the Space Station (i.e., beyond the proposed capability of the early 1990's) and develop guidance and advocacy for appropriate technology development initiatives.

Questions of Senator Heflin and the Answers Thereto

SPACE STATION

Question 1. NASA requested $235 million from OMB for Space Station definition studies in fiscal year 1985. You received $150 million. In the widely acclaimed Hearth report of several years ago, it is stated that many past failures of NASA

programs to stay on schedule and within budget were due to inadequate and underfunded definition studies.

Is history repeating itself; are we already beginning to shortchange our definition studies?

Answer 1. Consistent with the findings of the Hearth report, the NASA fiscal year 1985 Space Station request to OMB was for the initiation of an extended multiyear definition effort totalling approximately $700 million (real year dollars). Despite the reduction in fiscal year 1985, we still plan to allocate approximately $700 million to definition and advanced development activities through fiscal year 1987 by rephasing the funding over that three year period. The major impact of the reduction in fiscal year 1985 will be a four month delay in the start of Phase B contract definition studies and a subsequent delay in the initiation of development contracts in fiscal year 1987. Since this rephasing is not a reduction of the overall allocation, our planning remains essentially unchanged.

Question 2. In your statement you indicate that NASA plans to develop an "automation plan" through the space definition studies to "utilize the best of both manned and unmanned modes" in the Space Station.

Would you elaborate on what this "automation plan" would entail?

Answer 2. The Space Station automation plan is intended to provide a design objective: a manned Space Station that will have minimal coupling and requirements for ground-based control, thus, reducing materially the on-going operations cost of the Space Station. The plan will also evolve the method by which an optimum partitioning of functions between man and machine elements would be determined during the definition phase of the program. The plan will make use of the expertise of both the university and industrial communities. Space Station automation capabilities should lead to advances in the state-of-the-art of expert and intelligent systems and robotics with positive spin-offs for ground-based applications.

Question 3. The Congressional Office of Technology Assessment is completing its study of Space Station alternatives. One alternative concept to NASA's Space Station concept which they identify would cost approximately $2 billion. For that cost, OTA states (in House Testimony) you could have four to six crew members, 10–15 kilowatts of power and a space-based orbital maneuvering vehicle (OMV).

Please provide the Committee with a written evaluation of this alternative.

Answer 3. The Office of Technology Assessment (OTA) study has not been completed and NASA has been provided no details upon which to evaluate the alternative which is broadly referenced on page 5 of their February 2, 1984, statement before the House Subcommittee on Space Science and Applications. It is noteworthy that OTA acknowledges that they have "not performed a detailed engineering study." Their testimony further states "it is our view that by making good use of already developed technology, keeping required modifications thereto to a reasonable minimum, employing modern, cost-conscious, commercial-like acquisition practices, and cost-sharing with other countries, the operational capabilities to meet scientific requirements and to allow low-earth orbit satellite-servicing could be obtained for a total cost of some $2 billion . . ." when the details and assumptions upon which this view is based are made available to NASA, we would be pleased to provide a written evaluation.

SPACE SHUTTLE

Question 4. (Extended Duration Orbiter) How much money would it cost to extend the on-orbit time of a Shuttle from the present 10 days to 20 days? Would this be a good investment?

Answer 4. We estimate it would cost approximately $100 million to $250 million and take about thirty to thirty-six months to develop. We have for a number of years looked at the potential need for an extended duration orbiter and have identified three areas in which an expanded capability could be useful: (1) Vapor Solution Crystal Work; (2) Complete Solar Track-Entire Pass; and (3) Full Earth Coverage, Polar Orbit.

Our analysis to date indicates that it would be very difficult to justify the major expenditure of funds, control and avionics changes which would be necessary to extend the duration beyond 20 days with no identified critical requirements for that time which could not be met more effectively by the Space Station.

Question 5. (5th Orbiter) The Administration again is not requesting money for a 5th Shuttle orbiter. How much of the industry term will we lose in fiscal year 1985? In other words, how quickly is our "production readiness" declining?

Answer. 5. The balance of funding between the inhouse effort and subcontractors in the fiscal year 1984 and fiscal year 1986 timeframe retains many essential ele-

ments of the orbiter build capability. However, the Downey/Palmdale assembly workforce will be phasing down with the delivery of Atlantis, scheduled for December, 1984, and we will experience some loss of production capability in the final assembly area. Operational and structural spares provisionings have been made to minimize the loss of capability with subcontractors. We have concluded that the loss of subcontractor production capability during fiscal year 1985 is relatively limited, but that there will be a significant deterioration in the subcontractor base during fiscal year 1986.

Question 6. (Shuttle operations) Recently NASA consolidated the Shuttle processing work under one contractor (Lockheed). How well is the transition going, and is the entire Shuttle processing operation becoming more efficient?

Answer 6. The transition of Shuttle processing responsibilities and functions to the one consolidated contract with Lockheed has been accomplished on the planned schedule; the transition is essentially complete. The only function not transferred to date is a small ground systems software development and support effort by IBM (about 50 people), which is not scheduled to be transferred until the end of fiscal year 1984. The basic hands-on processing functions were transferred from Rockwell, Martin Marietta, and USBI on February 3, 1984. Lockheed is processing the flight hardware for the STS 41-C and 41-D missions. It is too early to have accrued cost accounting records of the improved efficiencies; however, Lockheed is meeting our previously planned schedules with a more streamlined workforce.

SPACE COMMERCIALIZAION

Question 7. What steps will you be taking to implement your task force report on space commercialization? For example, will you be appointing an Associate Administrator for Space Commercialization? You requested $5 million of OMB for space commercialization activities. Your got zero. Why was that, and what type of signal do you think that decision conveys to industry regarding how committed this Administration really is?

Answer 7. The organizational location of the office is under final review. There are a number of items in the budget that deal directly with the commercialization of space: materials processing, support of ELV's, reduced rate launches, and engineering support of a number of Memorandum of Understandings (MOU's) and Joint Endeavor Agreeemnts (JEA's). It is anticipated that the new office will be established and a specific set of commercialization requirements be developed for 1986.

UPPER STAGES

Question 8. With the past year, we have experienced failures in the Air Force's Inertial Upper Stage (IUS) and commercial Payload Assist Module (PAM). In the former case, we were lucky and were able to save the TDRSS satellite, but in the latest incidence, we lost two communications satellites.

What would be the impact on our communications and satellite industries of an unavailability of PAM's?

How much confidence do you have that we will be able to solve the problems assocaited with the IUS and PAM's?

When will the next flight using an IUS and the PAM's be?

Answer 8. NASA projects an average of two PAM's on every other Shuttle flight through 1988. Specifically through December 1985, there are 13 PAM's manifested. The impact on communications and satellite industries cannot be addressed quantitatively by NASA, but would certainly be substantial.

We believe with a high degree of confidence that the PAM and IUS problems will be resolved.

The IUS control anomaly encountered by the second stage during launch of TDRS-A has been extensively investigated by an Air Force/NASA/Industry team. The cause of the anomaly has been identified and corrective design changes are being implemented. This has been a lengthy, painstaking process which we believe will result in a fully operable upper stage.

The PAM anomaly is being investigated by an industry team led by McDonnell Douglas with NASA and DOD serving in an advisory capacity. While the team started its investigation a little over a month ago, we believe the problem will be solved in a timely manner.

USAF PAM missions are likely to precede NASA launched missions. Current NASA schedules call for launch of a Hughes Galaxy-C communications satellite using PAM to be launched by a Delta ELV in May, 1984. The next Shuttle launch is a Telesat mission with PAM in June, 1984.

The current projection of the IUS ready-to-launch capability is late November, 1984, with the next TDRS launch occurring in March of 1985.

GRAVITY PROBE-B

Question 9. I have seen some very impressive support for the Gravity Probe-B program from some of the best known scientists in the U.S. and from the National Academy of Sciences. The program certainly seems to have a staying quality since it has been going for more than 20 years, and I believe that it represents the kind of thing that NASA should be doing. Do the budget plans for fiscal year 1985 and beyond adequately support the accomplishment of Gravity Probe-B? At what level are you anticipating the support of Gravity Probe-B in fiscal year 1985 to fiscal yer 1990.

Answer 9. NASA is currently developing plans for the engineering development of Gravity Probe-B (GP-B) we believe that the individual component technologies necessary for the mission have reached an adequate level of development. It is perceived that the challenges and risks now largely reside in integrating these component technologies into an instrument with the demonstrated capability of performing the necessary precise measurements. The plan under development addresses the development of an instrument with the required capabilities. If the plan is implemented, it would be closely monitbred and, assuming successful completion and appropriate projected costs, could lead to the development of a spacecraft and flight instrument for accomplishment of the actual mission.

NASA is planning on making of about $5 million available for GP-B in fiscal year 1985. Funding levels for fiscal year 1986 and subsequently will not be determined until an overall plan has been completed and accepted.

ORBITAL MANEUVERING VEHICLE

Question 10. NASA has recently issued an RFP for the definition studies of the Orbital Maneuvering Vehicle (OMV).

When does NASA plan to initiate development of the OMV, and when would it become available?

Why was NASA's request to OMB of $10 million for the OMV in fiscal year 1985 turned down?

Answer 10. OMV is a proposed new start candidate for fiscal year 1986, with first flight unit availability scheduled for fiscal year 1990 if approved.

It was decided that with the initiation of the definition of the Space Station and the initiation of the Orbital Maneuvering Vehicle (OMV) Alternative Systems Concept Studies (Phase B Definitions) in fiscal year 1984, the OMV flight development start could reasonably become a high-priority fiscal year 1986 candidate. Commensurate with that decision, we have made the study length 12 months instead of seven months to permit further definition of the OMV.

SPACE APPLICATIONS

Question 11. (Materials processing) NASA's budget for materials processing is now a modest $23 million. The OMB cut NASA's request for fiscal year 1985 by $4.6 million. If materials processing in space has such potential economic payoff, whi isn't NASA spending more money to do high risk research?

Answer 11. During the past year, OSSA has taken steps to reorganize and strengthen the management and role of the microgravity discipline to take full advantage of the operational Space Shuttle; we believe that the proposed fiscal year 1985 funding level will allow us to build a solid base for future activity in this area. Our approach has two facets; the first is a continued strong ground research program with heavy university participation. In addition, we have placed a great deal of emphasis on identifying how more flight opportunities could be made available to the microgravity community, and consequently, we are aggressively pursuing the development of instruments, which can be flown on the Shuttle orbiter middeck. Emphasis is being placed on the construction of small, relatively low-cost instruments for flight. As more actual flight experience is gained, we anticipate a growing understanding of the effects and benefits of microgravity on various processes and, therefore, the means to effectively direct the program to those areas from which the most benefit can be gained. The key to this approach is continued involvement in the program by both industry and the university communities.

Question 12. I understand that a number of commercial firms are interested in materials processing in space, and a few are participating in the MPS program.

(a) Who is participating now, and what are we doing to engage the interest of additional commercial firms?

(b) What areas of MPS offer the highest commercial potential?

Answer 12. Currently there are nine industrial investigators involved in the microgravity program, as well as four companies developing flight hardware, two Joint Endeavor Agreements (JEA) and four Technical Exchange Agreements (TEA). These firms are as follows:

Investigators: Lockheed; Aerodyne Research Technology, Inc.; KMS Fusion; S. Gelles & Assoc.; EG&G; Marveloud; and Grumman Aerospace (2).

Flight Hardware Development: General Electric; Intersonics; Westech Systems; and TRW.

JEA's: McDonnell-Douglas; Microgravity Research Associates.

TEA's: John Deere Co.; Honeywell; INCO; and Dupont.

A "Dear Colleague" letter is being prepared which specifically solicits proposals from industrial investigators. In addition, we intend to aggressively pursue Joint Endeavor Agreements and Industrial Guest Investigator programs with firms interested in microgravity effects.

The research areas of greatest interest to commercial entities are those with a high market value. Two specific areas that have been identified as having a high market value are pharmaceuticals and semiconductors.

Question 13. (Communications) In addition to the $87 million which OMB cut for the ACTS program, the OMB cut $7 million from other communications initiatives. What would that $7 million have been used for, and why was it eliminated?

Answer 13. The $7 million would have been used to augment communications research and analysis activities. The $7 million was eliminated in deference to higher priority items within the overall NASA program.

Question 14. Last year this Committee asked NASA to undertake a study of the future of space applications. This study was to be similar to what the Solar System Exploration Committee did for NASA. How far along are you on this applications study?

Answer 14. As of October 1983, a subcommittee of the NASA Advisory Council (NAS) was formed to complete and recommend an appropriate role for NASA in Earth System Science and to develop an implementation strategy for this NASA program. The subcommittee held meetings in December and February and will meet again in early April. A week-long summer study is planned in mid-June to deal specifically with the identification of key scientific questions in each of the major disciplines and to attempt to prioritize their urgency. We anticipate additional sessions in the subsequent months leading to formulation of an implementation strategy by mid-1985.

SPACE SCIENCES

Question 15. Among the OMB cuts made in space science, they cut $17 million from planetary exploration research and analysis. These cuts will almost exclusively impact our universities. How can you justify such reductions?

Answer 15. Support for the scientific community, primarily at universities, from the Planetary Exploration Program, occurs through involvement in the flight programs as well as through the research and analysis program. The requested budget reflects the difficult balance that NASA has sought to achieve in planetary exploration between mission activity and supporting research. It should be noted that the inclusion of the Mars Geoscience Climatology Orbiter as a fiscal year 1985 new start does result in a significant increase in the overall budget level of the Planetary Exploration Program and will provide support for the university community over the next several years.

The Physics and Astronomy budget request also shows a substantial increase from fiscal year 1984 to fiscal year 1985, and as with the Planetary Exploration program, support to the scientific community occurs through both the flight programs and the research and analysis/mission operations and data analysis funding. Therefore, we believe we do have a balanced Physics and Astronomy program which will continue to support the scientific community, including universities.

Question 16. $5 million was again deleted this year for the Space Plasma Laboratory. What will be the impact of that cut?

Answer 16. The first flight of the Space Plasma Laboratory will have to be delayed somewhat beyond the date that the OMB budget request assumed as a result of the $5 million reduction.

Question 17. Life sciences experiments targeted at understanding what causes space motion sickness were cut by $4 million. Why? Don't we continue to experience problems with "Space Adaption Syndrome?"

Answer 17. An augmentation to the Life Sciences research targeted at understanding what causes space motion sickness of $4 million was denied. $2 million additional funding will be derived from monies that will be redirected from Life Sciences program areas of lesser priority. Such program areas include those medical problems in which either substantial progress has been made or which can be deferred pending a solution of the space adaptation syndrome problem. In fiscal year 1984 almost $5.5 million will be expended on the Space Adaptation Syndrome Project and on the closely related Neurovestibular Dysfunction research. With these monies Life Sciences was able to establish a NASA Space Biomedical Research Institute at the Johnson Space Center as well as to begin work on a number of key facilities to support research on the Space Adaptation Syndrome. It is now considered possible to sustain this activity in fiscal year 1985 without requesting an additional $4 million. Even though the Space Adaptation Syndrome still affects Shuttle astronauts it may be possible to make substantial progress in preventing it as a result of research which has come to fruition in fiscal year 1984. This research includes, in addition to much progress in ground-based studies, significant findings in vestibular experimentation conducted on STS–8, SL–1 and STS–41B.

AERONAUTICS

Question 18. In your statement you note your expectation that the Numerical Aerodynamic Simulator (NAS) will be initially operational in 1986 and fully operational by 1987.

Can you outline the specific actions NASA expects to take in 1985 to achieve this time frame?

Could you also describe exactly what the Cray High-speed processor will do and how it will improve existing aerodynamic simulation?

Answer 18. The first high-speed processor, the first CRAY 2 super-computer, will be delivered to the NAS Project in mid-1985. This high-speed processor is the heart of the initial NAS system and the key component around which the extensive, user friendly subsystems are assembled. In preparation for the delivery of the CRAY 2, a uniprocessor (CRAY 2 simulator) will be delivered to the NAS Project in mid-1984. This CRAY 2 simulator will initiate the development of the NAS Processing System Network (NPSN) control and operations software. This software development will continue through 1985 leading toward the 1986 initial operational status for the NAS system. The use; of the CRAY 2 simulator will allow smooth integration of the CRAY 2 into the NAS system when it is delivered and allows for a much shortened development period before initial operations commence.

During 1985, the NAS system networkd development will continue with the acquisition and integration of critical subsystem components into the NAS network. The critical subsystem components include additional work stations to provide access to the NAS system through the support processing subsystem and acquisition of the components for the first phase of the long haul communications subsystems which will allow initial remote access to the NAS. Additionally, the first phase of the graphics and mass storage subsystems acquisitions will occur which are required to support the output and analysis of large data-producing solutions/simulations. The combination of the work station, support processing, mass storage, and graphics subsystems is critical to the successful initial operation of the NAS system. To assure that the NAS system atains its initial operational status, test and integration activities will intensify throughout 1985. During 1985, an FRP will be issued for the operations support contractor leading to the selection of a contractor to support the NAS initial operations three support contractors: systems software development contractor, test and integration contractor, and operations support contractor.

Current computational aerodynamic methods are limited by available computer speed and memory. Improvements in computational methodology have been advancing at a much greater pace than large-scale computers, resulting in the advanced application of computational aerodynamics being restrained by available computer systems. The projected sustained computing rate of the CRAY 2 operating on applications-oriented aerodynamic codes is 250 million floating point operations per second (mflops). This rate of computation is about 4 to 5 times greater than that of the most powerful existing machines. Even more important will be its extremely large main memory of 64 million words which is about 16 times greater than now available.

The large increases in speed and memory will substantially improve the aerospace community's capability to solve heretofore intractable problems of national importance and to conduct pathfinding research that will form the foundation for applications on the even larger machines that will become available later in this decade. For example, the CRAY 2 will permit, for the first time, computations of the aerodynamic performance (including effects of viscosity) of relatively complete aircraft configurations throughout their flight envelopes. These early results will provide valuable new insights into the complex flows associated with maneuvering aircraft. These new insights will lead to methods for improving fuel efficiency of commercial transports and maneuvering performance of military fighters and missiles.

Another group of problems that can be treated much more effectively with the CRAY 2 are those associated with propulsion systems, both airbreathing and rocket. Internal geometries of propulsion systems and the associated flow physics are inherently complex. The speed, and particularly the large memory of the CARY 2, will greatly enhance the computational treatment of these problems and this will lead not only to improved designs but to shortened design cycles.

The understanding of turbulence physics will also be improved considerably when the CRAY 2 becomes available. For instance, problems dealing with the manipulation of turbulent-flow drag through minute modifications to surface texture and geometry can be addressed with computations for the first time. Experiments have shown potential for as much as 20 percent reduction in turbulent flow drag through these modifications but the underlying physics are not understood to the degree required for full-scale applications.

In summary, the CRAY 2 will permit the next major step to be taken in the development of applications of computational fluid dynamics.

Question 19. This is the second year of the Advanced Composite Structures Technology program (ACST), with the ultimate goal of "full use" of composites in primary airframe structures.

What is your definition of full use of composites in the development of commercial airframe structures?

Answer 19. Previous NASA programs have developed composites technology for applications in both secondary and medium-size primary structures of large transport aircraft, and the use of composites for these purposes is now considered state-of-the-art. New aircraft, such as the Boeing 767, incorporate literally thousands of pounds of composite secondary structure and the industry routinely includes composite stabilizer medium-size primary structure in near-term advanced aircraft designs.

The term "full use" of composites in primary aircraft structures means that an aircraft developer can confidently design advanced aircraft with large-size, heavily loaded composite wing and fuselage structures without undue risk of premature failure or unanticipated costs of development, maintenance, and repair. This further means that a validated technology data base of sufficient depth is available to permit both the developer to select composites for the design of strength critical wing and fuselage structure, and for government organizations to subsequently certify the use of composite primary structure in advanced aircraft. The data base must include verified analysis techniques which reliably predict structural lifetime characteristics under all anticipated environmental, usage and loading conditions, as well as consistent and reproducible manufacturing procedures.

The "full use" of composites will allow the designer to select composites from a list of qualified engineering materials, based on performance and cost advantages for the intended application, for the design of any structural component of an advanced aircraft.

Questions of Senators Riegle and Inouye and the Answers Thereto

Question 1. How competitive are U.S. made satellites with those available from other countries?

Answer. Since the launch of SYNCOM-1 in 1963, the United States has been the recognized technical leader in the design and manufacture of commercial communications satellites. All 37 of the INTELSAT spacecraft procured since that organization's founding have been built by U.S. prime contractors and, at least through the next generation (INTELSAT VI), this will continue to be the case. Of all the international commercial communications satellite contracts which have been let, it was not until recently (1981) that a non-U.S. firm was selected as prime contractor; even in that case (ARABSAT), a substantial portion of the total contract value will come to the United States. Technically, the U.S. industry is strongly competitive.

However, a number of countries (among them Japan, France, Germany, and Canada) have embarked on government-supported programs designed to increase their competitiveness in this burgeoning international market. In some cases, this support takes the form of government-provided or upgraded facilities; in some cases it is reflected in a favorable financing arrangements and offset commitments; and in some cases it is the result of increased government R&D funding. Each of these factors, operating singly or as part of a coordinated program, can work to undermine the competitive position of U.S. vendors, and perhaps neutralize a clear technical advantage they may have.

Question 2. If a foreign country told U.S. government officials that the purchase of a U.S. satellite was "unthinkable," what would be your reaction? What do you think should be the reaction of the U.S. Government? Which countries, if any, currently have—or are considering—barriers to the purchase of U.S. satellities? Please describe any such barriers, or considered barriers, in detail—country by country.

Answer. NASA, of course, deplores as a matter of principle any restrictions on U.S. industry's ability to compete for business abroad. However, NASA does not follow systematically the trade or procurement practics of other countries which is a responsibility of the United States Trade Representative (USTR) and Department of Commerce. I believe that your questions refer primarily to the Japanese government position on the procurement of communications satellite from abroad. I am advised that this is a trade policy matter which is under intensive negotiation between the Japanese authorities and other parts of the Executive Branch (USTR and Department of Commerce). For this reason, I believe the detailed information you seek could be obtained best from USTR or Department of Commerce.

Question 3. Do you believe that barriers to U.S. suppliers of telecommunications satellites and launch services should be removed?

Answer. Yes. The international telecommunications market, both ground and space segment, is growing at a breathtaking pace. It is an arena for which the United States is ideally suited to compete. Market factors which distort the operation of free-trade decisions, based on reliability of delivery and product, cost, and technical confidence, can only work to the disadvantage of the United States over the long run.

Questions of Senator Lautenberg and the Answers Thereto

ACTS

Question 1. Please submit for the record a discussion, in detail, of how the ACTS program would develop and advance technologies neither in use in civil satellites operating today, nor contemplated in the Hughes proposal.

Answer 1. The technologies which will be advanced by the restructured ACTS program and which are not in use in communications satellites operating today or contemplated in the Hughes proposal, include electronically hopped spot beams, message switching on board the satellite in the base band processor and the use of adaptive power control for rain fades to conserve satellite weight and power.

The high-speed scanning of the spot beam allows dynamic coverage to occur in response to fluctuating user demands. Each scanning beam only needs to cover areas that have communications needs at the moment and only needs to dwell there long enough to satisfy those needs.

Use of multiple spot beams require a switching system on-board the satellite to interconnect the beams and route signals, or messages to their appropriate destinations. The base band processor is the heart of the scanning spot-beam system and provides efficient routing of low-volume communication from small earth terminals, such as those located directly on the customer's premises. The base band processor reduces the signals received by the satellite down to their base band content, digital data consisting of binary ones and zeroes. These data are then stored in the base band processor memory and routed to their correct destination. In addition to permitting signal error detection and correction, the base band processor will provide highly dynamic routing of individual telephone calls and, in essence, move the switchboard from the ground to the sky.

The ACTS ground test program will develop these technologies and evaluate them in an overall system simulation.

Question 2. Is it true that ACTS will more efficiently use spectrum space? Does any current satellite, or the Hughes proposal offer the same efficiencies? How will ACTS do it? Do you agree that conserving spectrum space is important? Why?

Answer 2. Both the restructured ACTS multibeam antenna technology and the Hughes technology will allow a single satellite to reuse the frequency many times, although the previous ACTS flight test had a potential capacity greater than the Hughes system. The Hughes filing indicates a two degree spacing; however, we now understand that the Hughes technology will potentially allow the same orbital arc spacing as the ACTS, but has initially limited its plan to two degree spacing.

Conserving spectrum is important. Recent studies indicate saturation by the early 1990's of the U.S. geostationary orbital arc by satellites employing presently used C and Ku frequency bands, even with consideration of expected evolutionary improvements in technology.

Frequency reuse, by employing multiple spot-beams from a satellite rather than a single beam (as with conventional systems), to provide domestic coverage promises significant increases in capacity from a given frequency allocation. By using the same frequency in many beams rather than just one, the same frequency allocation can be used many times by a single satellite thus increasing its capacity many fold. This technique would be applicable to all bands, C, Ku, and Ka, but would be particulary advantageous at Ka-band, where the technical characteristics are more favorable to the generation of spot-beams and there is five times the frequency allocation of either of the other bands. Both the NASA and the Hughes system would operate at the Ku band.

Question 3. In your staff's summary comparison of the Hughes proposal and the ACTS, it is noted that the Hughes satellite will offer: "Ka band technology applicable to specific markets peculiar to 16 major city sites." On the other hand, ACTS will provide "Generic Technology Extendable to all bands, wide variety or market, with ubiquitous coverage to all 50 states."

Is it not true that ACTS will, if permitted to proceed, open areas of our Nation—rural areas—that do not have access to satellite communications right now because of economic or technical impediments that ACTS will overcome?

What is it about ACTS technology that will give it this greater reach to rural areas, to all 50 states?

Answer 3. The restructured ACTS technology using electronically hopped spot beams and onboard message switching will potentially permit communications with areas of the country which are less densely populated and which have lower communication densities. Its use at Ka band will depend in part on whether it proves to be economically attractive relative to other alternative technologies operating at C and Ku bands. The Hughes filing is intended to provide communications between population centers where local aggregation of communications at ground sites is possible. The Hughes proposal is based on Hughes judgment as to what is the best way to initially tap new markets with advanced technology. ACTS technology allows time sharing of satellite resources such as power, antenna beams, bandwidth, etc., on an as needed basis. For example, a location within a hopped beam is served or assigned resources only for as long as they are needed. Hughes has stated that its approach will provide highly efficient service to high-density routes in metropolitan areas.

Question 4. A major component of ACTS is its high speed band processor. If ACTS does not go forward as a flight program, do we not open the door for some other nation to commit the funds to flight test that base band processor? What is to prevent that from happening? What is so significant about the technology of the base band processor?

Answer 4. A U.S. company could agree to sell a base band processor to a company in Europe or Japan as part of a foreign experimental program, only if authorized by the technology transfer control processes required by U.S. law (e.g. Munitions Act).

The technology of the base band processor is crucial for implementing the narrow beam electronically hopped satellite antenna capability. The processor allows storing routing and switching individual messages from one beam and one burst to another. In its operational form, the ACTS base band processor technology will perform the same function as the SS-4 switching complex for the whole city of Chicago. It is literally, technology for a switchboard in the sky.

Question 5. There is an obvious effort on the part of NASA to promote commercial endeavors in space. These endeavors must, however, rely upon the promises and follow-through of NASA.

I understand that private industry has invested millions in ACTS-related development. Private companies, participated in an open bidding process. They were prepared, I understand, to commit over $100 million in private funds. Indeed, last year you called this, "A novel procurement approach including a cost/risk-sharing arrangement with industry." Does not the Administration's reversal on ACTS reflect poorly on NASA's reliability in such joint ventures? Do you believe that NASA's

reversal on ACTS is going to have an impact, the next time private industry considers a venture with NASA as partner?

Answer 5. We believe that the restructuring of ACTS demonstrates NASA's ability to adapt to changing circumstances. Private industry proposed to do many of the same things we were planning to do with the ACTS flight test. The Hughes filing demonstrates a willingness of U.S. industry to apply advanced technology to open new markets, using private capital.

ACTS SATELLITE/FOREIGN R&D

Question 6. In a recent NASA publication, entitled: "ACTS—advanced Communications Technology Satellite," it is stated: "The efforts by the Japanese and similar activities in Europe, particularly in the areas of spot-beam technology and Ka band advance, are serious threats to the U.S. lead in satellite technology, systems, and market share. It has become clear that without appropriate Government support, the U.S. satellite lead will be lost, following the unfortunate precedent established in the consumer electronic industry."

Please describe, the basis for this statement. Please include a description of the current state of the satellite development effort in Japan and Europe. What is the level of technological development in Japan and Europe? What is the current level of government spending and what has it been in past years? What evidence is there that Japan and Europe are becoming increasingly competitive in the world market for satellite and satellite-related equipment?

Answer 6. As the U.S. satellite communications R&D slowed after 1973, the Japanese and European efforts accelerated. By 1978, for example, the Japanese had already launched an experimental direct broadcast satellite (BSE) for tests and preliminary operations in the Ku-band. Although the early satellites in the Japanese satellite communications program were bought from U.S. industry, all subsequent models have had an increasing domestic content, particularly when advanced technology was used. It is also noteworthy that the Japanese have become the leading supplier of INTELSAT earth stations and, because of very advanced technology and established production lines, are likely to take the world market lead in the sale of TV receive-only (TVRO) earth stations designed specifically for direct broadcast reception. Some see these efforts by the Japanese and similar activities in Europe as serious threats to the U.S. lead in satellite technology, systems, and market share.

In the next five years, Japan is expected to make significant gains in space technology. In August, 1983, the second CS-2b was launched as an in-orbit spare, ensuring operational service in the 30/20 GH_z band. Earlier that year, CS-2a was successfully launched, providing NTT with eight transponders in the 30/20 GH_z and 6/4 GH_z band for business data, facsimile, and video service. Japan's expenditures in the Ka-band greatly exceed the U.S. effort, although these expenditures are partly to buy technology from us for the operational use.

The formal Japanese space budget was $493 million in 1983. This budget is smaller than that of NASA's and does not reflect the participation of Japanese industry which, it is estimated, would increase the total investment in space to between $1 billion to $2.4 billion in 1983. However, a comparable $1 billion planned for the U.S. Milstar Satellite program must also be recognized. Milstar has been the source of important technology advances, including some advances planned for use by Hughes in its new civil satellite proposal.

By far the most ambitious ESA project is L-Sat. The satellite is envisioned to be in the 4,000 pound class, an advanced experimental communications satellite to test the feasibility to direct TV broadcasting and specialized/business communications using small roof-top size terminals. With Ka-band, L-Sat will incorporate multi-feed antennas of about 4 meter diameter which can provide beamwidths less than 0.25° giving "footprints" centered on major cities of less than 150 km diameter. The British have been most enthusiastic about L-Sat development, which is seen as competitive with U.S. technology for future INTELSAT satellites. British Aerospace has been awarded the prime contract. The estimated launch is planned for 1987. In June, 1983, an announcement was made that the commercial version of L-Sat, called Olympus, would be marketed by British Aerospace, Fokker, Aeritalia, and Selenic Spezio.

Another foreign effort is the Italian Italsat, scheduled for launch in 1987-88. Italsat is designed for Ka-band global and spot coverage. Propagation experiments at 50/40 GH_z are also planned for European coverage.

In a study of the potential world market performed for NASA by Western Union, the worldwide communications satellite market was forecast to total $35 billion to $50 billion between 1981 and 2000, split approximately equally between spacecraft

and earth station hardware. The Western Union report also states that approximately one-half of the world market, $16 billion to $20 billion, will be within the United States and that the competition from the Japanese and the Europeans for the United States and the rest of the world satellite market will be keen.

Question 7. As stated in "ACTS—the Advanced Communications Technology Satellite" (NASA) AT PG 7: "The goal of the flight system and the experiments to be performed with it is to complete technology development to a level of technical risk acceptable for industry implementation." One of the arguments for a flight-demonstration program is that only Government would be willing to commit funding for long-term high-risk, high-cost program demonstrating substantially untried new technologies. Id. at p. 3.

On the other hand, industry would be more likely to fund low-risk, near-term projects. Ibid. in light of the fact that the Hughes proposal represents an incremental technological step with near term applications, does it not support the argument for a flight-program for ACTS? In other words, does not the Hughes proposal demonstrate that although industry will make noteworthy advances, it will not achieve the leap-frog of technology sought in ACTS and deemed necessary to meet the challenge from competing Nation?

Answer 7. The Hughes filing indicates the willingness of U.S. industry to perform a part of the ACTS technology development. The remainder of the technology development, e.g. base band processor and electronically hopped spotbeams, will be developed as a part of the NASA restructured ACTS program. The assumption is that the combination of these efforts and the NASA ACTS ground test program will provide enough momentum to provide the U.S. industry with sufficient technology advancement to meet the challenge from competing nations.

Question 8. You stated that if NASA proceeded with its plans to flight-test ACTS, it would pose unfair Government-sponsored competition to the Hughes proposal. (1) Is it the case that ACTS is an experimental satellite which would not itself be used commercially? If ACTS were flight-tested and successfully proved itself in 1989, by what year would it likely be possible to build and fly a commercial version of ACTS? When is the Hughes satellite scheduled for launch? In other words, how many years would Hughes be free to operate its satellite without competition from a commercial satellite utilizing all the technology of ACTS? (2) To the extent ACTS competes with the Hughes proposal in the sense that it would eclipse the Hughes technology, does not ACTS "compete" with all existing commercial satellites in which the private sector has invested?

Answer 8. The original ACTS flight program was an experimental satellite which would not have been used commercially. Operational use of ACTS technology would not be expected until the mid-1990's. The Hughes satellite is scheduled for launch in the 1988 time frame. The ACTS technology would augment existing commercial satellite technology by providing a generic technology for electronically hopped spot beams and message switching.

THEORETICAL ASTROPHYSICS

Question 9. Since 1981, the fraction of the Physics and Astronomy budget committed to Research and Analysis has declined from over 10 percent in fiscal year 1981, to close to 5 percent proposed for fiscal year 1985. What is the justification for the decreasing emphasis on Research and Analysis?

Answer 9. The change in the Research and Analysis budget from fiscal year 1981 to fiscal year 1985 in proportion to total Physics and Astronomy funding does not reflect a decreased emphasis in Research and Analysis activities; rather, it is due to two things: (1) major elements of the Physics and Astronomy Research and Analysis budget (notably space plasma physics and the solar-terrestrial theory program) have been transferred to the space applications budget line item since 1981, and (2) compared to fiscal year 1981, funding profiles for ongoing development flight programs—Space Telescope and the Gamma Ray Observatory—are essentially at peak funding rates in fiscal year 1985. Therefore, it should be noted that Research and Analysis was and is now very important and receives much emphasis within NASA.

Question 10. What has NASA done to implement the several recommendations of the National Academy of Science and NASA advisory groups concerning the establishment of university-based programs in the area of theoretical astrophysics? Is it true that these proposed programs are relatively inexpensive, but provide the infrastructure on which new missions are based and the foundation upon which information from existing missions can be analyzed?

Answer 10. NASA has, for many years, supported research in theoretical astrophysics under the Supporting Research and Technology and Data Analysis projects

within our Research and Analysis program. In response to the recommendations of the National Academy of Sciences and NASA advisory groups; however, we plan to initiate a separate astrophysical theory program within Research and Analysis. In fiscal year 1985, we plan to fund the program at a level of approximately $1.0 million, which should support three to five research groups. The program will be announced to the scientific community through the vehicle of a Space Science and Applications Notice, which we plan to release in mid-1984. Scientific knowledge is advanced by both theoretical and experimental research. Both types of research are necessary to assure that an infrastructure is maintained to support new missions as well as to analyze information from existing missions. The R&A program is the prime source of funds for both of these elements.

Question 11. Please discuss NASA's activities in the education of graduate level scientists in space science? Are there currently fellowship programs available to support graduate students at universities and is there sufficient support for graduate students through research grants at universities? How does the total number of students currently supported compare with NASA's predictions for the need for space scientists with advanced degrees in the future?

Answer 11. NASA does support a graduate student researchers program which was initiated in 1980 and provides graduate fellowships Nation-wide for approximately forty new awards each year to post-baccalaureate U.S. citizens to conduct their thesis research at a NASA field center. Selections are made on the basis of a proposal submitted by the student's faculty advisor, who subsequently will be responsible for the student's performance. Specific research areas of interest to NASA are identified by the participating NASA field centers.

NASA estimates that $250–$260 million of the fiscal year 1985 budget request will actually go to educational institutions. These funds will support some additional graduate students over and above specific graduate student researchers mentioned earlier. We believe that we are providing sufficient support for universities to meet the future needs for space scientists with advanced degrees.

EXCLUSIVE TRADE POLICIES IN AEROSPACE

Question 12. Please describe the level of participation in NASA programs by the Japanese. Please refer to any role they have played or have been invited to play in the future as contractors in NASA projects, as teammates in research and development, and as recipients of American technology.

Answer 12. Japanese industry have not been a prime or subcontractor in any NASA project. On occasion, and consistent with NASA procurement regulations, Japanese materials or products have been procured by NASA or its contractors/subcontractors for use in NASA activities. Such procurements have averaged less than $500,000 per year. Similarly, NASA has not been involved with a Japanese agency in a joint development project, such as Spacelab with Europe and the Remote Manipulator System (RMS) with Canada. We are not aware of any current plans by a U.S. company to team with a Japanese company to respond jointly to a NASA Request for Proposal for definition or development of a planned NASA project.

However, over the years NASA and counterpart Japanese agencies engaged in space activities have carried out a number of cooperative activities, ranking from ground studies to flight projects. In addition, NASA has provided reimbursable launch and tracking services for Japanese spacecraft. All of these activities are summarized in the publication 25 Years of NASA International Programs, on pages 24, 25, 53, 54, 72, 73, 78, 80–87, 89–91, 93, 94, 115, 119, 120 and 121. (This NASA publication is currently being updated.)

The major current NASA activities with Japan include:

Planned reflight on the Earth Observation Mission (EOM–1) of the Space Plasma Accelerator (SEPAC) scientific facility developed for flight on the first Spacelab mission by Japan's Institute of Space and Astronautical Science (ISAS). The SEPAC is the first major cooperative project between NASA and ISAS. It was developed by ISAS and Japanese industry at an estimated cost of about $30 million. It achieved impressive scientific results on the first Spacelab mission. NASA is currently discussing with ISAS possible cooperative arrangements for a reflight.

NASA is discussing with ISAS possible contribution of a Japanese scientific satellite for the planned U.S.-Europe-Japan International Solar Terrestrial Physics (ISTP) program. ISAS would design and develop one of the basic spacecraft for this multi-satellite program. The spacecraft would include Japanese and U.S. scientific instruments and NASA would launch it on the Shuttle. This potential cooperative scientific research project is subject to approval as a future new start, respectively, by the United States and by Japan.

Japan's National Space Development Agency (NASDA) is actively planning its First Materials Processing Test (FMPT) mission to be flown on the Shuttle/Spacelab on a reimbursable basis in 1988. This mission will emphasize materials processing in space and will consist of about one-third of a dedicated Spacelab long module mission. Japan is also actively planning to fly a payload specialist on this mission. An invitation to do so was extended by President Reagan to Prime Minister Nakasone during the latter's visit here in 1983.

In response to NASA's invitation, Japan's NASDA organized a Space Station task group in 1983 to coordinate Space Station requirement and mission analysis studies. Japan is actively interested in possible participation with the U.S. in the Space Station activities. We will be having more detailed discussions with the Japanese on this possibility in the near future.

Japan's National Aerospace Laboratory (NAL) has proposed a technical information and pilot exchange program between their Quiet, Short Takeoff and Landing (QSTOL) research aircraft and NASA's QSRA project, both of which utilize upper-surface-blowing (USB) propulsive lift for short takeoff and landing research. Preliminary discussions have been held between NASL and NASA, and potential benefit to the United States has been identified. The proposed initial exchange of pilots would likely enhance Japanese QSTOL project confidence as they approach their first flight, but would not transfer significant U.S. technology. In exchange, receipt of information and experience from the OSTOL project would augment NASA's USB data base. Discussions are continuing with NAL on the possibility of establishing an agency-to-agency agreement which would define an exchange program that will assure equal benefit to United States/Japan.

A basic guideline for NASA's international cooperative activities is that each party funds its own efforts and meets its own obligations in a joint project by use of its own technology and capabilities (no exchange of funds). Indeed, a major consideration for NASA before committing to a joint project is prior confirmation that a prospective foreign partner has the domestic capability to carry out its planned responsibilities. Although NASA's cooperative international partners work closely with us and receive needed interface information, their contributions result from their existing capabilities and not from transfer of U.S. technology.

Question 13. Despite the extension of the open-procurement agreement with Nippoin Telephone & Telegraph, Japan's foreign minister Abe recently reiterated his nation's firm position that procurement of American satellites was out of the question. Meanwhile, Japan is tring to develop its own industry (as it did in semiconductors and computers). Japan's Space Agency was reportedly planning to spent $145 million to develop two new communications satellites for launch in 1987. When we consider Japanese participation in NASA programs, do you think it is appropriate for us to consider also the nature of Japanese trade and industrial development policies in the aerospace fields?

Answer 13. It is appropriate to consider the Japanese trade and industrial development policies in the aerospace fields when we consider potential Japanese participation in NASA programs. However, the first task before us in our Space Station discussions with the Japanese is to see if we can agree on a Japanese contribution that will considerably enhance the Space Station program.

The history of cooperative activities in space has proven that these activities benefit both the United States and its cooperative partners. Cooperation permits the United States and its partners to share the cost of mission. The partners' contributions combine so that, in many cases, the resultant missions have capabilities which far exceed what any single partner could pursue along. Furthermore, cooperation has permitted the United States access to other foreign resources, such as foreign expertise and foreign ground sites, which have provided invaluable support to our space research programs.

Conduct of cooperative programs has always been governed by six principal guidelines: (a) projects are identified as being of mutual programmatic interest to the participating partners; (b) projects are based upon the capability of each side to meet the technical and financial requirements of its contribution; (c) projects are based on no exchange of funds; (d) projects are conducted through arrangements with respective Government agencies; (e) projects are based on clean technical interfaces; and (f) projects are consistent with U.S. foreign policy. Consistency with broad U.S. foreign policies is the final filter in the conduct of all our international cooperative programs. This is the point at which questions related to U.S.-Japanese trade relations are considered, and it is an important assessment which we take seriously.

Question 14. Would you be agreeable to exploring the scope of this problem with the Committee and devising an appropriate response?

Answer 14. We recognize that the response to this problem goes beyond NASA's responsibilities. We intend to discuss this fully with other responsible parties in the government, and would be agreeable to exploring the problems further with this Committee.

MANNED SPACE STATION

Question 15. There seems to be a tension between two apparent goals of the Space Station. On the one hand, we may view the Station as a means for fostering international cooperation and good will. On the other hand, we see the Space Station as a means of enhancing America's technological edge—and its presumed economic spin-offs. However, if other nations are going to contribute to the cost of a Space Station, they are going to want to enjoy the returns—in prestige and technology.

(a) How should be balance these considerations?

(b) Indeed, would America predominate the statellite communications industry worldwide if it had cooperated more with other nations and shared more with others our technological gains?

Answer 15. We, as a Nation, cooperate with our allies in the Atlantic alliance and elsewhwere, yet at the same time we do compete with these very same allies in the world's economic market places. While there is some tension between the two, it is manageable. The Space Station program should be no different. By cooperating with our allies and friends on Space Station, the United States is acting in a manner fully consistent with our role as the leader of the free world. Our prestige should not be lessened by the cooperation of other countries. On the contrary, it should be heightened.

Economically, we believe the Space Station will open up significant opportunities for us to reap scientific and commercial benefits. It is our intent that the participating countries will retain their intellectual property rights and proprietary data. We expect that our partners will develop (using their own technology and funding), and contribute major segments that extend the capability of the Space Station. In return for such contributions, our partners expect access to and use of the facilities and capabilities of the Space Station. We foresee that the total returns from the Space Station can be increased by these additional capabilities.

It is clear that America dominates the satellite communications industry worldwide at present because judicious judgments were made about where, and where not, to cooperate. There has been extensive international cooperation in satellite communications. For example, the earliest trans-Atlantic satellite communications were received in Europe by a number of countries which built, at considerable cost to themselves, ground stations to cooperate with the United States in investigating this new mode of communications. In addition, several nations have conducted telecommunications applications projects using NASA experimental satellites (CTS, ATS). This involvement has contributed to the expansion of new applications of space communications worldwide and opened new markets for U.S. telecommunications hardware and services. The Intelsat system, whose membership includes over 100 countries, was established because of a U.S. initiative and led to rapid expansion in the international use of space communications. More importantly, because Intelsat has procured much of its hardware from U.S. suppliers, it has also contributed to many advances in the U.S. space communications technology industry.

Question 16. There seems to be a general agreement that a Space Station project is going to force advances in robotics, artificial intelligence, and other fields. But, why is a Space Station the preferred way—given the costs of the project—to achieve advances in these fields? Could similar advances be achieved at less cost, on the ground, without a Space Station?

Answer 16. The Space Station project, per se, will not force advances in robotics, artificial intelligence and other fields. However, since the number of men aboard the Space Station will be limited and since the Space Station will be limited and since the Space Station will be developed as a multi-functional entity, it is crucial that the Space Station function in an exceedingly efficient manner. One element that is important in achieving efficiency is to take maximum advantage of automated elements including robotics and expert systems to perform some functions without man and to perform other functions by increasing man's ability. One major challenge in the development of the Space Station is to define the optimum partitioning of functions between man and automated elements.

It must be stated that the Space Station is not being developed for the sole purpose of developing these automation technologies. However, it is logical to assume that the automation efforts leading towards an increase in Space Station efficiency will serve to drive these technologies for the benefit of the general industrial sector.

It is difficult to estimate whether similar advances could be achieved through ground-based activities inasmuch as terrestrial activities would be quite different from those performed in space.

Question 17. In the early stages of the manned Space Station program, considerable work will have to be done in defining the kind of Space Station to be developed, in terms of cost; engineering; technological or economic goals; and the extent of international cooperation. What kind of guidance should the Congress provide to NASA during this early stage?

Answer 17. During the early stage of Space Station definition, a number of key policy issues need to be resolved. For example, the roles of our friends and allies in a U.S. Space Station program should be debated thoroughly. A number of related issues require clarification. What elements of the Station should potential participants seek to develop? What kind of benefits, if any, should they expect to receive from us in return for their contribution? Is there a role in the Station for nations with less experience in space than the countries usually associated with the Space Station? On questions like these, policy guidance from Congress will be necessary.

Question 18. Please describe any possible military uses of the manned Space Station that have been discussed by NASA and or DOD.

Answer 18. DOD study efforts to date have not identified military requirements that uniquely justify a manned Space Station. When a permanent Space Station becomes available, certain technology development missions related to national security might be performed through Space Station capabilities.

Question 19. What has been the substance of discussions with the military regarding possible uses of the Space Station?

Answer 19. Lacking any military requirements, the Department of Defense (DOD) is taking an evolutionary approach to Space Station, i.e., specific requirements must be demonstrated before a policy change will be made. NASA is continuing to keep DOD up-to-date with briefings to key Air Force and Navy personnel.

Senator GORTON. Gentlemen, we welcome you to this hearing. I understand that Mr. Hawkins and Mr. Brizendine do have formal written statements. The statements of each of you will be included in the record in full. I would request that you limit your oral comments to 5 minutes each.

We will hear from each of you in order and then we will submit questions to you.

Mr. Hawkins.

STATEMENTS OF JOHN C. BRIZENDINE, CHAIRMAN AEROSPACE SAFETY ADVISORY PANEL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; WILLIS M. HAWKINS; CHARLES J. DONLAN; HERBERT E. GRIER; NORMAN R. PARMET; SEYMOUR C. HIMMEL; AND GERARD W. ELVERUM, JR., MEMBERS

Mr. HAWKINS. Senator Gorton, I thank you for the opportunity.

We have a lot of content in the stuff we have submitted to you, both the summary which was submitted to you, and the full report which we delivered to NASA about 2 weeks ago is also contained. You can read that in detail.

This is my last performance as the Chairman of the program. I have served on the Aerospace Safety Advisory Panel for a long time. I regret having to leave, but the fact that my previous company had a successful competition causes me to have a conflict of interest.

The same goes for a member in our organization who is from Grumman, who has also left the panel. Therefore, John Brizendine is going to take over as Chairman of the Panel for all subsequent activities.

What I propose to do is just go over a list of the items that we listed in the 1982 report, only to emphasize the fact that most of

those items still exist, and we would like to put some emphasis in NASA's programs to try to get some of these off the list.

We questioned the instrumentation adequacy both for the structural integrity and for the performance demonstrations out in the corner of the envelope, that is, to show the maximum performance that the shuttle can get. We think that they have not completed the R&D program in that regard.

We think that they need to have substantially more emphasis on organization for operations. NASA is not used to organizational operations, and we think it probably takes more emphasis from headquarters in order to make this possible.

Maybe a lead center is all right, too, but the fact of the matter is the organizational people need to be put into a powerful position so that they can outline the maintenance, outline the spares, outline the logistics necessary to make this an operational and low-cost vehicle, as low-cost as it can possibly be.

We suggest that sustaining engineering for the operation be separated from R&D engineering, and we suggest that some certification policy be demonstrated or actually developed so that the certification of changes in the shuttle can be streamlined.

We proposed and annoyed NASA substantially on demonstrating the autoland. During this year we have looked at what the problems are in the autoland and the problems the pilots would face in this demonstration, and we have taken off some of that pressure. We think there is more R&D yet to be done before that autoland really ought to be demonstrated.

We have made some suggestions on the main engine, and we think the turbo machinery on the main engine is going to have to be partially, if not fully, redesigned before they get up to the rating on the main engine they would like to use ultimately on the shuttle.

We have suggested that they approach the margins on their new program as substantially different. We have also suggested that they take a hard look at the landing gear. The fact of the matter is that the landing gear in most normal airplanes is not designed by the landing condition. The shuttle is in a unique condition, a very unique position where it is only used in landing, and therefore, having designed it up to its absolute maximum strength of all of the materials, it is not demonstrating the reliability that a normal landing gear is expected to demonstrate, and we think they should put more margin in the landing gear and brake design.

Those are the lists for 1982. In order to abbreviate my statement, I would like to say that we include almost all of those in 1983. We have taken the pressure off from the autoland. We think they should think that thing through before they make the demonstration, mostly because of the fact that one of the real problems the shuttle has is that it is not a normal airplane. On landing it has instabilities, it has lags in the control reaction to changing its angle of attack and the rapidity with which it picks up lift. So, it is a very difficult device to land.

The real problem is that the autoland system, if something went wrong with it just at the last moment and the pilot was asked to take over, he would not have the momentum of the approach, if you will, in order to make that landing manually. We might put

the shuttle at substantial hazard because of the fact that he had to take over when he really didn't have the feel on how he would get it on the ground to begin with.

Therefore, we think that substantially more work needs to be done on the shuttle, and we have one major suggestion in 1983 as to what they ought to do.

Now, the two things that we have talked about that are new in 1983 had to do with a request directly from NASA to take a look at their product quality and utility. This was a request that they asked us to review because every time they have a difficulty in the shuttle they change the quality assurance system.

It has now gotten to be such a fine sieve that it is very difficult to get anything through it. That means everything is delayed in order to be certified as safe. We think this is a delay that is unnecessary and that they could rearrange their system right down to and including the engineering so that they can take a look at changes in the shuttle when they have difficulties, changes in the shuttle where they realize they have obsolete technology in the shuttle, so that they can streamline the certification of these changes and get more modern equipment in the shuttle.

The design in the shuttle is quite old and they are going to have to, before they get fully operational, make some major changes. The system by which they make those changes has got to be safe, the way it has been in the past, but it could be streamlined.

We have also suggested that the flying qualities which caused the problem with the autoland system and caused some of the problems with the brakes could be improved, and we suggested that they go to one of their other centers and have a major study to see if they cannot change the pitch control system on the shuttle.

We suggested that canards might do the trick and that Langley Research Center be asked to look at it and then Johnson Space Center look at how it could be incorporated in the machine. If you could increase the lift coefficient of the shuttle by a factor of two, which we think you could do, then you have got yourself a substantial improvement on the loads on the landing gear. You might make ditching possible. You would reduce the size of the airport that was required, which opens up an awful lot of emergency airports for you, and we think that that should be looked at very hard.

I think that the only thing I would not like to comment on, because of conflict of interest, is the fact that they have made one step in the direction of operations in the contract they have issued down at the base, and I would like to have Herb Grier, who was the former president, make a comment on how he feels about the SPC.

Herb, can you do that?

[The statement follows:]

STATEMENT OF WILLIS M. HAWKINS, CHAIRMAN (RETIRED), AEROSPACE SAFETY ADVISORY PANEL

Mr. Chairman and Members of the Subcommittee, this is my last appearance before your subcommittee as Chairman of the Aerospace Safety Advisory Panel. As I retire from the Panel, I welcome and introduce to you the new Panel Chairman,

John C. Brizendine. Since John will be in charge for 1984 and beyond, I will discuss only our calendar year 1983 findings, conclusions and recommendations and he will discuss future Panel activities along with any comments he may have regarding our report to you. Other changes in Panel membership are noted in our Annual Report dated January 1984. This report forms a part of my statement and is attached.

The Panel held its annual meeting on February 15, 1984 at NASA Headquarters and presented its detailed report to the NASA Administrator and Deputy Administrator. As in previous years, Panel fact-finding sessions have been conducted on the average of four times each month. Members and consultants visited seven NASA facilities, as well as NASA Headquarters, and numerous NASA contractors. Although our attention has been primarily focused on the Space Transportation System, there have been a number of visits to assess aeronautical operations and attendant flight safety. All of our efforts have been supported by the Panel Staff Director through in-depth and continuous participation in NASA activities.

The Panel's report to you last year covered eight primary concerns:

(a) The adequacy of instrumentation and flight plans to demonstrate the vehicle system performance envelope.

(b) The demonstration of structural integrity and a cautious approach to performance improvements.

(c) That STS operations, although different from an airline's, could benefit from airline logistics and maintenance procedures to minimize turnaround time without jeopardizing flight safety, and that a unique organization should be developed to achieve this.

(d) Sustaining engineering for STS operations might best be served by divorcing it from the normal R&D engineering functions at the NASA Centers.

(e) Policy and standards for hardware/software certification and the need for NASA policy and an independent certifying function.

(f) Autoland for the Orbiter.

(g) Space Shuttle Main Engine turbomachinery limitations and the required redesign for life and high performance.

(h) The need to take a hard look at the current Orbiter landing gear subsystem.

For this hearing, I propose to summarize our current concerns, some of which are "carry-overs" from previous years. Included are Panel suggestions which might resolve these concerns.

1. Product Quality and Utility becomes more important now that the major task for NASA and its contractors is more one of replacing and fixing during turnaround, along with gradual system enhancements to reduce cost or improve performance of the Space Transportation System. Emphasis must be placed on assisting contractors and subcontractors to produce the highest quality of product oriented toward operational suitability. A basic concern is that the design for most of the Shuttle components is at least ten years old. Industry has progressed and new developments and design concepts have produced better and more reliable products. This, coupled with difficulty in the reproduction of older units, suggests that design change may be essential to achieve maximum reliability. The problem that this concept aging process poses is that NASA cannot allow changes in design or substitutions in components without requalification of the hardware along with comprehensive consideration of the effects of the change. It would seem to be in order to determine in advance the extent of obsolescence, cost versus reliability improvements, the "delta" qualification requirements for such updated equipment, and establish a priority plan for design modernization.

2. The current design of the Space Shuttle Main Engine, with the exception of the turbomachinery, appears to be suitable, assuming satisfactory completion of the specified acceptance tests. Suitable in this case means seven flights at full power level of 109 percent of the original rated power, called "100 percent." The turbopumps providing high pressure oxygen and hydrogen working at the 109-percent level are currently only suitable for one or two flights before removal for teardown and inspection. The Aerospace Safety Advisory Panel agrees with NASA's prudent decision to limit the operation of these engines to the 104-percent thrust level which reduces the engine internal loads permitting more flights with greater operating margin. The Main Engine project has embarked on a three-phase program to achieve a long-lived, reliable full-power level (109 percent) engine. The Panel supports this organized approach to achieve adequate reliability and performance of the engine. The Panel emphasizes the importance of setting objectives in terms of demonstrated margins of stresses, temperatures, loads, etc., rather than trying to achieve arbitrary running time at a given thrust level. Having demonstrated improved margins, it is important not to operate at the highest level tested, but to operate at performance levels where these prudent margins are not violated.

3. The Orbiter main landing gear continues to concern the Panel. We feel that a complete structural and mechanical suitability review should be made by an engineering team with commercial transport experience for the purpose of suggesting alternative landing gear configurations and setting target margins for structures and the wheels, brakes, and axles. It appears that there are some less extensive improvements that might be worthwhile:

(a) Move the tire centerline inward toward the shock strut about one inch and increase the tire size as much as the diametrical clearances will allow.

(b) With the larger tire and internal wheel space, redesign the brake for greater energy and torque capacity using structural carbon.

(c) Support the brake on the axle near the inboard bearing to minimize the impact of axle bending.

4. Logistics, maintenance, supply and support programs received much more NASA attention as the positive impact of such programs on reliable and safe mission operations for the total Space Transportation System was recognized. Considerable progress has been made in meeting current Space Transportation System logistic needs but the demands of 24 flights per year by 1988 requires further steps and investment. The Integrated Logistics Panel which provides the coordination not only between various NASA organizations but also between NASA and the United States Air Force is alive and well. However, to meet the needs of the future it appears to the Panel that NASA and its contractors should face up to:

(a) Establishing a single authority that is responsible for all logistics to support the Space Transportation System.

(b) Establishing an overall maintenance plan to provide for operations in the next decade.

(c) Clearly establish the roles and responsibilities of the Shuttle Processing Contractor at KSC in the overall logistics scheme.

(d) Establish the necessary logistics plans to support major payloads and payload elements such as the Spacelab, Centaur and Inertial Upper Stages.

5. Orbital structural integrity at all points within the "flight envelope" still requires flight data and analyses beyond that currently available. The initial flights of the Space Shuttle were designed to be reasonably benign with trajectory and performance capabilities to be expanded with each flight. Only a bare minimum of valid flight data is available to validate predictions of structural loads to assure that the safe strength of the vehicle is not exceeded. This applies to all Orbiters, but it is more critical for Orbiters 103 and 104 whose structures were lightened in a weight reduction program. To operate the Orbiter up to its safe strength with confidence, aerodynamic loads in ascent and thermal loads in descent must be more thoroughly defined. To do this, the Panel recommends the derivation of a new set of loads based on the latest wind tunnel and flight data and further recommends that the final derived structural loads be validated with full-scale flight data. This will require sufficient sensors placed at critical locations on the fuselage and wings along with a recording system of large enough capacity and data rate to obtain firm confirmation of the assumed loads and their distribution.

6. Orbiter landing speed and pitch control concerns have been discussed by the Panel in prior reports. Excessive landing speeds and control sensitivity result in:

(a) A continuing potential for a landing accident. (b) Limitations on choice of abort sites. (c) Risk of destructive brake malfunctions. (d) Non-survivable open sea ditchings. (e) Lengthy and expensive training programs.

Program management recognizes these problems. The Panel has looked at "wing tiplets" and "canards" to alleviate some of the undesirable control characteristics and recognizes the difficulties inherent in their incorporation. The Panel has followed the many, more simple approaches to the improvement of the flight controls during landing and none of these—software modifications, revised feed-back paths, etc.—appear to be powerful enough to overcome the inherent instability and the impact control movement on lift coefficient. The lack of a landing incident to date is a tribute to the skills of the astronauts, and to the carefully planned and executed training program. Nevertheless, it is the Panel's view that major control and lift coefficient improvement will be required for future operational success.

7. The Shuttle Processing Contract, which consolidates under a single contractor all ground processing and launch and landing services, went into effect October 1983. The Lockheed team which includes Grumman Technical Services, Inc., Morton-Thiokol, Inc., and Pan American World Services, Inc. will make the final transition, assuming all responsibility at Kennedy Space Center, following the launch of STS mission 41-B (February 3, 1984) so that they will be fully responsible for the next launch STS-41-C in April 1984. The planning, preparation, and initial actions taken by both the SPC and NASA appear to be thorough and working well

so far. The Panel believes that NASA can further help the Space Shuttle Contractor in carrying out its responsibilities through such actions as the establishment of a unified logistics system, the acquisition of an adequate number of spares, the definition of major and minor overhaul sequences, and the development of coordinated launch schedules for Kennedy Space Center and Vandenberg Air Force Base. The Shuttle Processing Contractor must be a full partner in planning major hardware acquisitions and enhancements that relate to Shuttle processing. Lockheed has created an "external" Safety Advisory Board (modeled in many respects after the Aerospace Safety Advisory Panel) that will meet quarterly to examine the safety aspects of their operations.

8. Safety of flight operations associated with both administrative and research and development aircraft were closely followed during 1983. Of note are:

(a) The revitalization of the Intercenter Aircraft Operations Panel which has provided a needed forum for the exchange of both safety and flight operations information.

(b) The reorganization in NASA Headquarters that established the Aircraft Management Office as the single office for directives and policy leadership for aircraft operations. This should provide leadership and more consistent communications.

(c) The recommendations from ECOsystems International, Inc. constructively reinforced many of the previously reported findings of the NASA in-house review teams to shore up communications and provide policy direction for flight operations. Panel members will follow the Headquarters-field relationships during 1984, and the field performance to see whether further augmentation of Headquarters "control" should be recommended.

The total report which we have delivered to NASA contains substantial detail on the logic which supports the Panel's conclusions and recommendations. An up-to-date list of Panel members, consultants and staff are listed in the report. Covered in the annual report are discussions of the Intertial Upper Stage propulsion units, Centaur propulsion systems, Extravehicular Activities (EVA) including space suits and the manned maneuvering unit, the Orbital Refueling Experiment, the Filament Wound Solid Rocket Case, and Lightweight External Tank. All of these received attention during the year and, with the exception of the External Tank, the Panel will continue to monitor these elements as they are further developed. The Filament Wound Case and the Centaur/Shuttle represent advances in the state-of-the-art and have safety implications.

John Brizendine will now discuss the Panel's plans for 1984, after which I suggest that the members of the Panel, with your permission, offer any comments that will augment, clarify or correct what I have presented. We are, of course, all available to discuss any areas of interest that you may wish to explore.

Mr. GRIER. Yes, indeed. The shuttle processing contract let at Kennedy Space Center, which coordinates the efforts of some 12 individual contractors, in our opinion is a step forward. The coordination of the various tasks just simply has to be improved.

In the last few annual reports, we have gently nudged, and sometimes not so gently, NASA to bring together the operational responsibility and appoint people who can in fact be held responsible for the operational, not the development, aspects of the shuttle. This is a step in that direction, a step implementing it. We feel it is good.

The performance of the contractor is pretty early, obviously. We have been following this, but the performance has been good. Their approach to their personnel relations—and after all, it is people that really make this system work—it has been excellent. And they have been recruiting the workers that have in the past worked for the various individual contractors. They have been recruiting substantial percentages of them, and they are integrating quite well.

We feel this is going to be a substantial improvement and a great aid to safety.

Mr. HAWKINS. I think that there may be many questions from your organization, but the fact is that over the year we have averaged almost three or four visits per month to various centers to

take a look at various parts of the shuttle. We have looked at the EPA, the Centaur, we have looked at the orbiter itself, and we have worked hard on NASA's aircraft safety, on their administrative safety programs, and have made suggestions there, and NASA has responded in every case.

I think we will be available. The people who are here from our organization should be able to answer the questions if you have detailed questions on those. I think we have covered most of the main critical points.

I would like to have John Brizendine talk about what he thinks they ought to be doing next year.

Senator GORTON. Mr. Brizendine, we will now hear your testimony. As was the case with Mr. Hawkins, the entire written testimony will be included in the record as if read.

Mr. BRIZENDINE. Thank you, Mr. Chairman. I will be very brief.

I would, as this is my first appearance before this committee, like to thank Mr. Hawkins for his excellent leadership of this panel. I know that the other members of the panel who have worked with him for a considerable time join me in that.

I think you will find our panel's mode of activity, the fact-finding process, will really continue as it has in the past. I have a good deal of admiration for the scope, depth and caliber of the panel members, and I believe the processes they have developed are quite effective.

In entering into this activity myself and discussing the program objectives with NASA management, one finds, particularly with the national space transportation system, very basic, solid objectives—reliability of the repetitive launch, the ontime launching, the performance of each mission, increasing the opportunities for the users to have more effective programs.

But at the top of the list in all of these cases, we find that safety assurance is the No. 1 issue in the minds of NASA management. Safety assurance involves many, many aspects. It is not just the technical side of things. And certainly, as we get into a pseudocommercial operation with multiple repetitive launches annually, it is going to involve much broader than the strictly technical and will be well into managerial concepts.

Thus, this panel does require a variety of expertise, and we will use whatever outside assistance that is necessary to fulfil the panel's obligations. Specifically, in 1984 we are focusing a majority of our time on the STS processing contractor. It is an example that we will follow closely.

Interface work is scheduled in the next week or so. In continuing this process, the maintenance and the logistics program is highly essential, absolutely essential to a successful achievement of the goals of the program. The development and certification of the components of the system to improve performance and improve the capability is a natural. It will happen.

But the manner in which the certifications are managed and decided, it is a good thing to do, it is safe to fly, it is something that this panel will watch carefully. We will be observing the individual payloads and the systems that are carried by the orbiter to utilize those payloads to put them into a useful position.

Again with respect to their effects on safety of the overall operation, we will continue to follow the matters of concern that are listed in the 1983 annual report, with emphasis on design suitability, on product quality, and the certification policy.

We will be delving for the first time into the space station. It is early and it is timely that this panel make its inputs so that those will be given timely consideration. We will continue to monitor NASA's other flying operations, its administrative and its R&D in-the-atmosphere type of flying.

Of course, we will perform any sort of special ad hoc panel functions that are requested of us from time to time by NASA management, and perhaps try to respond to any particular concerns or questions that your committee may have.

I personally look forward to the opportunity to work with you. Thank you very much.

[The statement follows:]

STATEMENT OF JOHN C. BRIZENDINE, CHAIRMAN, AEROSPACE SAFETY ADVISORY PANEL

Mr. Chairman and Members of the Subcommittee, this is my first appearance before your subcommittee as the new Chairman of the Aerospace Safety Advisory Panel. I want to thank Willis Hawkins, the retiring Chairman, for his excellent past leadership of the Panel and for his summary covering the many facets of Panel activities this past year. As he noted, I will describe briefly the Panel's efforts for 1984. Attached to my statement is a brief resume of my own background, for the subcommittee's information. Since retiring from my last position as President, Douglas Aircraft Company, I have been doing consulting work with the broad aerospace industry.

The Panel's fact-finding mode will continue as before and, where necessary, I would expect to bring specialists into this fact-finding where needed to meet the Panel's obligations.

In discussing the programs objectives for the National Space Transportation System with NASA senior management, I find they list "Safety Assurance" first followed closely by: increasing reliability, on-time launch performance, cost per flight reduction, payload performance increase, increased user opportunities, and maximum capacity utilization. This same basic listing would most likely be applicable to all manned space and aircraft operations and is one which we heartily support. In providing its "Safety Assurance" assessment, the Panel, as you can see by the material in our annual report, examines many related program areas, both technical and managerial. Thus you will find a variety of expertise among the Panel members and consultants.

Panel activities in 1984 will continue to focus on a number of aspects of the Space Transportation System as it approaches full operational status. We will include at least the following areas:

1. Shuttle Processing Contractor progress at Kennedy Space Center including their working relationships with NASA Centers and associated contractors.

2. Space Transportation System Maintenance and Logistics plans and their implementation, including the NASA-Contractor-Air Force coordination for both ground and flight hardware and software.

3. Payloads and Upper Stage Propulsion Systems and their interfaces with the ground and flight Space Shuttle System. These will include the Centaur, Inertial Upper Stages, Payload Assist Modules and specific payloads such as:

(a) The Orbital Refueling Demonstration showing on-orbit transfer of hydrazine propellant from a storage tank through a zero-G servicing system into a flight-type propulsion module. The Panel is interested in the certification process for the hardware and software, the safety analyses dealing with Extravehicular Activities in the Payload Bay and the handling of hydrazine.

(b) The Tethered Satellite System demonstrating deployment of a tethered subsatellite as far as 100 kilometers from the Orbiter. This system has potential for safety concerns when one considers the variety of possible system configurations, the complexity of multibody tethered dynamics, the deploy and control system, and the numerous operational constraints associated with deployment, stationkeeping, and retrieval.

4. Development and certification of Space Transportation System component improvements such as the Filament Wound Case for the Solid Rocket Motor and the Orbiter Main Engine Refinements.

5. Other STS matters of concern noted in the Panel's 1983 annual report, with particular emphasis on design suitability, product quality, and certification policy.

The Panel will begin a review of the Space Station, from the viewpoint of understanding the technical management approach to assuring that "safety" in all its ramifications are a part of the program and that any Panel comments or recommendations are provided early enough to be evaluated and where required . . . factored into the program in a practical manner.

We will also continue to monitor NASA's policy, procedures, and management of safety assurance for both administrative flying and research and development flying.

We will, as requested by NASA, support special study and ad hoc teams such as was done this past year where Sey Himmel worked with the Space Shuttle Main Engine and Orbiter Auxiliary Power Unit teams and Dick Battin worked with the Orbiter General Purpose Computer committee.

I appreciate this opportunity to have introduced myself and the near-term plans for the Aerospace Safety Advisory Panel. It will be my pleasure to work with you and your staff as well as with the NASA and contractor organizations to further assure safe and successful aerospace operations.

Senator GORTON. Thank you.

Mr. HAWKINS. May I add one thing? In talking about the members who are here and the members who did contribute, because we did not put it in our statement to you, I would like to state that one of the major contributors to this report this year is a chap by the name of Robert Rothi, who was a member of our panel. He was our landing gear expert, our mechanical and controls expert. And he passed away. But he did make a major contribution to this. I would like to see that his name is in the record.

Senator GORTON. We are delighted to have that comment in the record, Mr. Hawkins.

On the last space shuttle mission, two communications satellites were deployed into incorrect orbits due to malfunctioning upper stages. What precautions might NASA have taken prior to the deployment to detect the defect on the upper stage engine nozzles?

Mr. HAWKINS. I think that this is an interesting question, but it involves the relationship of NASA and its commercial customers. With respect to the safety panel itself, our concern with anything that goes into the payload bay is to whether or not it can hazard the shuttle and its mission. There was no hazard for any of this that we could see on either one of the satellites.

The development of the solid rocket motor which appears to be the culprit in this case was strictly a commercial development. I think NASA has no responsibility whatsoever for its performance other than whether or not it would hazard the shuttle itself and its mission, which it did not.

I think we are aware of what did happen. I think we are aware that there was a background of experience with this particular solid rocket motor that suggests that it would not happen. But the fact is that there is a ground test previously in which an error like this did occur. I am sure that commercial operators are now sweating out how they are going to do it and whether or not what changes there are for the next flight.

A similar problem, of course, occurred in the Air Force launch some time ago, when they had a solid that failed. That too we looked at in some detail, but it was not NASA's responsibility, nor

was it ours, other than the safety of the mission itself. As far as we are concerned, that was a satisfactory payload for the shuttle.

Senator GORTON. Mr. Brizendine, in your testimony you indicated that the panel will begin a review of the safety dimension of the space station. What are some of the safety considerations that are inherent in such a station? What kind of problems do you expect to face?

Mr. BRIZENDINE. Well, I think at this point they are omnidirectional. Of course, we are concerned with the whole system and particularly the manned interfaces.

I certainly agree with the previous testimony that the performance in these programs is extremely important to the image of our country. I consider a successful execution of the program—while we may be talking safety primarily, a good performance on safety will undoubtedly mean a good performance on the overall program.

We have the opportunity in the space station to start at square one, so to speak, and observe the concepts, how the various technologies will be employed, how they interface, how the human will be interfaced with the applications of the technologies and the processes of developing, managing, and operating the station.

I am at a loss, Mr. Chairman, to give you detailed specific answers to your question.

Senator GORTON. Next year you expect to be able to be more specific, I take it?

Mr. BRIZENDINE. We will be a tad smarter, we hope, next year.

Senator GORTON. Thank you very much.

By reason of the constraints of time, I will defer the rest of the questions which I have. I do have a number of other questions, which we will submit to you in writing.

Senator Heflin, we will turn it over to you, and I will ask you to bring the meeting to a close when you finish with your questions.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORTON AND THE ANSWERS THERETO

Question 1. The two communications satellite mishaps on the most recent Shuttle mission have led NASA to suggest that there may be a "national and international problem" for every rocket motor using carbon composite materials. Further, NASA has said that new design models and inspection techniques are needed.

(a) Until new designs and inspection techniques are implemented what are the safety implications for NASA's Space Transportation System?

(b) Is this a problem that should have been detected and resolved earlier?

(c) What steps should NASA implement immediately in addressing this potential problem?

Answer 1-(a) The Panel believes that at the moment there is no direct safety problem.

We will monitor activities associated with resolving these rocket motor problems to assure there is no safety impact. Since the rocket motors are fully "safed" while within the payload bay, as are the satellites as well, they meet the safety requirements spelled out in such standards as NASA NHB 1700.7A., "Safety Policy and Requirements For Payloads Using the Space Transportation System." If there are "lessons learned" from these rocket motor problems, NASA should apply them as appropriate.

1-(b) Based on the available data, at this time, it is not apparent that this problem should have been detected and resolved earlier. The investigation teams are currently working to define the problem, the cause, and resolution. With a background of 16 successful firings and little, if any, instrumentation on the motors it may be difficult to resolve the problem.

1-(c) NASA's experience on composites indicates that process controls, adequate testing, and inspection are keys to suitable hardware. As noted in 1-a above, these units are not NASA procured, however, the lessons learned in NASA's composite work should be available to the industry team working this problem.

Question 2. Last April, the Intertial Upper Stage (IUS) deployed the Tracking and Data Relay Satellite (TDRS)-A into an incorrect orbit, now two Air Force missions have been cancelled because of the IUS problems have not been resolved.

(a) Should NASA consider using an alternative upper stage to deploy TDRS-B and C?

(b) If not, is NASA proceeding properly towards ensuring the highest degree of reliability for the IUS?

Answer 2-(a) It is our understanding that NASA has investigated alternates to the IUS following the IUS failure. Although we have not examined this work in any detail we presume that their analyses to date has not shown a clear-cut alternative.

2-(b) The IUS is an Air Force responsibility along with their contractors and NASA has and continues to support the engineering team that is working to resolve the problems with the techroll seal and interfacing system. The Panel believes NASA is proceeding in a proper manner to help achieve the desired technical results.

Question 3. In your January, 1983 report to the NASA Administrator, you stated that the landing gear tires and brakes have proven to be marginal and constituted a possible hazard to the Shuttle. In your January 1984 report, you again expressed these same concerns. In the most recent Shuttle mission, and on previous missions, there have been problems with the brakes.

(a) In light of your recommendations and concerns relative to the brakes, has NASA properly addressed these problems?

(b) If not, what should NASA do to properly address these problems?

Answer 3(a). A number of things have happened during the past few months which indicates that NASA and its contractors are now seriously addressing this issue. A team of industry and government engineering experts, including those with commercial transport experience, met in January 1984, to review the braking system and to suggest improvements. Industry representatives included Bendix, Douglas Aircraft, Boeing, General Dynamics, Grumman, Lockheed and Northrop. Government representatives included NASA and the Air Force. The experts have provided NASA with a number of recommendations which are currently under evaluation. The Panel has not seen their report as yet. The Panel has not seen their report as yet. The Panel understand that one of those recommendations is being implemented now, it is planned to instrument selected flight vehicle brake assemblies to determine the exact cause of the brake problems. Manufacturing quality controls and inspections have been strengthened to weed out such things as minutely cracked carbon liner retaining washers and undersized thermal slots in the rotors and stators.

3(b) We will continue to monitor the activities associated with the resolution of this continuing problem, and we will be discussing this with NASA at JSC in late April at a full Panel fact-finding session. It is suggested that NASA: (1) determine the cross-wind limitation imposed on landing the Orbiter under maximum weight conditions, and (2) determine why the KSC landing resulted in severely damaged tires and what should be done to alleviate this problem. Our suggestion of automatic braking will also be reexamined.

Question 4. Your January, 1984 report mentions that the Orbiter Structural loads have not been validated. What risks or dangers exist in not having these Orbiter structural loads properly validated?

Answer 4. The unavailability of flight data to validate the current best predictions of structural loads raises questions about how best to exploit the full strength of the orbiter. To the extent that all the needed data are not available it has been necessary to placard the vehicle so that it flies begnign trajectories. The mission planners have been careful to constrain flight trajectories. This, of course, limits the performance of the system. The inability to validate the original design loads has particular significance for Orbiters 103 and 104 whose wing structures appears more critical than earlier vehicles owing to the 800 pound weight reduction in wing structure. The new "6.0 loads/stress cycle," given the go-ahead in late 1983 with scheduled completion in 1985 should provide a more accurate picture and is currently concentrating on critical structural areas. We understand that additional instrumentation (strain gauges, pressure sensors, thermocouples) are being installed on Orbiters-099, -103, and -104 to aid in this process.

Question 5. In your testimony, you indicate that the Shuttle landing speeds and landing flight controls contain a noticeable risk and that the lack of landing inci-

dent to date is a tribute to the skills of the astronauts and to their training program. What are the risk and dangers that have been avoided to date and what should NASA do to reduce or eliminate these risks?

Answer. 5. The fundamental issue arises from the configuration of the wing and aerodynamic control surfaces, more specifically the lift characteristics of the wing with control surface deflection. When nose-up pitch control input is made (elevon trailing edge deflected upward), two things happen which create adverse conditions: (1) there is loss of lift, which causes the orbiter to sink more rapidly, and (2) there is a shift in pitching moment which requires further pilot control action to balance. The combination of loss of lift and pitching moment change requires exceptional pilot skill to avoid possible over-control and resulting divergent oscillation. One means of avoiding large excursions in lift and pitching moment is to approach the landing at higher speed. This has generally been the practice. (Higher landing speed, of course, increases the loads on the landing gear and brakes.) Thus the panel has recommended that means be provided to control the orbiter pitch attitude without the adverse affects noted above. One means could be the use of pitch controls physically separated from the wing, such as canards surfaces (located in the vicinity of the nose of the orbiter).

Question 6. In your January, 1983 report you expressed concern about the safety of the Shuttle's auxiliary power units (APU's). On the last two Shuttle missions the APU's have experienced problems. Over the past year, how has NASA responded to your concerns about the auxiliary power unit?

Answer. 6. The Panel has been pressing for improvements in the APU concept for sometime and has made a number of suggestions for NASA's consideration. These have included the use of an hydrogen/oxygen fuel in place of the present hydrazine. Other candidates for improvement were the water spray system for oil cooling, the character of the oil itself which demands cooling, and the complexity of a system that has been "added-to" to meet in-service demands. We understand that in November 1983 a contract was signed to develop improvements and to reduce the complexity of the APU's. During the Panel's fact-finding session at JSC in late April we will determine the status of this area.

Senator HEFLIN. I only have a couple of questions.

Mr. Hawkins, as retiring Chairman of the Aerospace Safety Advisory Panel, how would you describe NASA's response to your panel's recommendations over the years?

Mr. HAWKINS. I would have emphasized that had I had a little more time. The fact is that I have been continually pleased and surprised at the openness of NASA to any of our inquiries. We have never, ever been in a position where we felt that we did not get all of the information about anything that we wanted anywhere in the NASA system. That is gratifying and helpful and shows the attitude that NASA has to what we are suggesting.

However, the design is like all designs: If it is not invented here, it is no damn good. So the guy from out of town has a little difficulty sometimes in penetrating a system, even though he seems to have all of the facts in the world.

I am disappointed at the response of NASA to a number of our suggestions which appeared to me to be fairly obvious. The landing gear is one. They have consistently maintained that the landing gear is perfectly all right. I think eventually the landing gear itself will talk them into making some changes.

As a matter of fact, they have had their first major meeting with other industrial people, people with more experience in normal landing gears. They have limited this meeting to the brakes, which have been a difficult problem for them. I think they will probably fix the brakes.

However, I think we now see signs that Johnson will respond and will put some more instrumentation on the landing gear and

find out how close to the margin it is operating. When they find that out, I think we will then get some changes.

Senator HEFLIN. That was my second question. I wanted to know what NASA's reaction was to your complete structural and mechanical suitability review of the shuttle's landing gear. So I reckon you have answered that.

Well, with that, unless you want to add anything else—would anybody else like to add anything about what was stated relative to the landing gear?

Mr. HAWKINS. Do you guys have anything more?

[No response.]

Senator HEFLIN. If not, we will bring the hearing to a close. Thank you very much.

Mr. HAWKINS. We will be happy to respond to your questions.

[Whereupon, at 11:55 a.m., the subcommittee was adjourned.]

NASA AUTHORIZATION FOR FISCAL YEAR 1985

THURSDAY, MARCH 1, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:10 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. This is the second of four hearings on the part of the Subcommittee on Science, Technology, and Space on the NASA authorization for fiscal year 1985.

In November, this subcommittee devoted a full hearing to the issue of a civil space station. At that hearing, NASA presented a detailed explanation of its studies to place in orbit a manned research lab and operations center. This was followed by testimony from outside witnesses on the need for and the commercial opportunities related to a permanent manned presence in space.

In his state of the Union address on January 25, the President announced a comprehensive plan for space, to build a permanently manned space station within a decade. The President invited international participation in this endeavor, and sought cooperation by Government and industry to develop the commercial potential of space.

The day before yesterday, the first day of fiscal year 1985 NASA authorization hearings, NASA Administrator Jim Beggs again discussed, among other things, the administration's plans for a civil space station.

Today, we will continue to examine this plan for a civil space station, with emphasis on several different factors and perspectives that could eventually play a significant role in the development of a space station.

The President's invitation for international participation in the development and use of a civil space station is a reasonable option to explore. We have enjoyed many joint space endeavors with countries the world over, beginning as early as 1961, when we launched with Australia the sounding rocket Skylark 4. Possibly our most significant international space endeavor occurred in November with the flight of the European Space Agency spacelab aboard the ninth space shuttle mission.

Today we will explore the possibilities and implications of continued international cooperation in developing such a station. An-

other issue we will examine today is how and to what extent automated systems or robotics are to be employed in the space station initiative. Developing the proper mix of man and machine is a crucial issue that could significantly impact the ultimate design of a space station. Our technology has made great strides since 1967, when the claw and arm of Surveyor 3 extracted soil samples from the surface of the Moon. The use of artificial intelligence, teleoperators, and robotics to free man to perform the more productive and meaningful work aboard a space station warrants our careful consideration.

Mindful of the fact that a space station will have an impact on each of us as taxpayers, we should also consider the interests of the private citizen and his or her views of this major space initiative. Similarly, a program of this significance will impact NASA's future policy considerations as well as the agency's future goals and objectives.

Today we will have the opportunity to examine these two perspectives as we focus on the President's call for a permanently manned space station.

We have several distinguished guests with us today. Our first witness, Dr. John Logsdon, will give a historical perspective of the space station issue and its related policy considerations.

Dr. Logsdon, if you will step forward, we will be delighted to hear from you.

Because of the length of the hearing today, we ask that each of the witnesses limit his formal testimony to 7 minutes, and each round of questions by members will be limited to 10 minutes each. I can assure each of you, beginning with Dr. Logsdon, that his entire written statement will be included in the record.

STATEMENT OF DR. JOHN M. LOGSDON, DIRECTOR, GRADUATE PROGRAM IN SCIENCE, TECHNOLOGY, AND PUBLIC POLICY, GEORGE WASHINGTON UNIVERSITY

Dr. LOGSDON. Thank you, Senator Gorton.

I welcome the opportunity to share my views with the subcommittee.

Really only twice before in the 26 years since President Eisenhower and the 85th Congress developed the framework for the U.S. space program has there been a similar occasion for a fundamental national decision with respect to that program's future.

One occasion was in 1961, as President John Kennedy, only 4 months after entering the White House, declared that it was "time to take longer strides, time for a great new American enterprise, time for this Nation to take a clearly leading role in space achievement which in many ways may hold the key to our future on Earth." That declaration introduced President Kennedy's commitment to lunar exploration, a commitment made in response to Soviet success in orbiting the first human and developed over a 3-week period in consultation with a relatively few individuals in leadership positions.

By contrast, the second fundamental decision in the history of the U.S. space program, to develop a partially reusable space shuttle, emerged from a 3-year-long, wide-ranging but rather inconclu-

sive debate over the future of the U.S. space program after Apollo. Early in this debate, the White House and Congress rejected as not appropriate for the times a NASA proposal that the U.S. post-Apollo space program should be built around the development of permanently manned space stations and space bases in various locations in the Earth-Moon region, and that the United States should prepare for long duration occupancy of the Moon and for manned planetary expeditions in the 1980's.

Out of this ambitious proposal, only the space shuttle, originally conceived as the logistics vehicle for low orbit space stations, proved attractive enough to gain the approval of political, national security, and technological leaders, and at that the decision to proceed with the shuttle was a close call.

Now President Reagan has proposed that Americans should follow our dreams to distant stars, living and working in space for peaceful economic and social gain, and has called upon NASA to develop a permanently manned space station and do it within a decade.

You and your fellow Members of Congress must decide whether you agree with the President's view that the substantial investment needed to both create and exploit this capability is in the national interest, not only this year but in years to come.

Make no mistake, a choice with so much influence on the future of the U.S. space program comes along only once every decade or so. It is useful, I think, to put those kinds of decisions in an overall framework and to ask now, as we consider the space station, how it compares with the situation which led to Apollo and the space shuttle, and, perhaps more importantly, what is different now.

One thing which is not different is the idea that a permanently manned orbital outpost is a key element in a long-range plan for the full exploitation and exploration of space. That notion is as old as the origin of space technology in the earliest years of this century, particularly in Europe, where Tsiolkovsky, Oberth, and von Braun all identified multiple advantages of bases in space.

The decision to go to the Moon shortcircuited early U.S. space station plans, but from the start of the 1960's, most NASA planning assumed that a space station was the appropriate post-Apollo goal. When NASA in 1970 found that it could not gain White House approval for simultaneous development of a space station and a space shuttle, and indeed that it would be fortunate to gain approval for a scaled-down shuttle program, the agency deferred—not abandoned—its station effort and made sure that any shuttle which might be developed could be used in constructing just the kind of modular space station now being proposed.

Nothing that has emerged from the results of the Skylab program in 1973, the Soviet Salyut program, or the shuttle program since 1981 has changed NASA's conviction that a serious commitment to space will require a space station. I think NASA must be commended for the way it has gone about laying the basis for a national decision on the space station, especially in comparison to the 1969 to 1971 period, when the organization put forth a rapidly changing series of proposals in response to White House pressures to minimize the space budget. Compared to the information when Apollo and the shuttle were began, there is now a rich base of ex-

perience and thought regarding the proposed space station program.

I must admit to being puzzled by persistent comments that NASA has not spelled out a vision of the future into which the space station fits. Anyone who has paid attention at all to planning for the U.S. space program or indeed for the Soviet space program would recognize that a space station has historically been seen as the central element which opens up all of space to human activity.

The Soviets are already acting on that vision, and have put in space a modest space station with the likelihood that a more ambitious one will soon be available. NASA provided a clear statement of its vision as long ago as 1969, when it put forth a strategic plan which at its most aggressive—and unrealistic—called for a space station by 1975, a 50-man space base by 1980, a 100-man space base by 1985, a station in orbit around the Moon by 1976, a lunar surface base by 1978, and the initial Mars expedition leaving the Earth in 1981. That plan, incidentally, was presented to this committee's predecessor, I believe, in this room on August 5, 1969. There seems to be little doubt that the decision underpinning the step NASA is proposing now is that of increasing man's capability to live and work in space until ultimately earth is seen as just the cradle of mankind. This is obviously an enterprise extending over decades, not years, and one need not totally embrace the vision of human exploration of the solar system to support the incremental steps, which have their own justifications, such as the shuttle and the station.

I think what is involved is faith in long-range tangible payoffs, but faith alone is a weak basis for a multibillion dollar investment if it were not accompanied by other strongly positive reasons for moving forward.

The reasons, I think, for going ahead is difficult to measure but nevertheless real factors such as national pride and sense of accomplishment; the impact of major initiatives in pulling along with them important areas of U.S. technology; the opportunity for engaging our allies in an effort directed toward common human aspirations; and the chance to demonstrate to all in this country and overseas that the United States will not turn its back on the leadership role in space.

When President Kennedy announced the Apollo commitment, he told the Congress and the Nation that he really wanted them to accept a firm commitment to a new course of action which would last for many years and carry heavy costs. Kennedy said, "If we are to go only halfway or reduce our sights in the face of difficulty, in my judgment, it would be better not to go at all."

We kept the commitment to Apollo. We did not do the same thing for the shuttle, and the shuttle program hit a lot of problems. Hopefully, we have learned from these experiences. If we are willing now to go only halfway, then it is probably better not to begin. It makes no sense, in my judgment, to develop a space station as a center of space activity if we do not also intend to remain active in space.

Thank you.

Senator GORTON. Dr. Logsdon, what would halfway be if we were to go halfway now? What would its consequences be both here in our own space program and with our foreign allies and supporters?

Dr. LOGSDON. It seems to me that a great deal of momentum has been built up, both in NASA and in its contractor base, toward the space station concept, a lot of thinking, a lot of ideas. We are ready to take the next step in the development of the program. If we reduce the amount of funds available for definition studies, which are the crucially important part of the whole development program, to make sure we understand what we are building and why we are building it, if we turn that down, if we reduce the momentum that has been built up, it seems to me that what one does is delay the program, stretch it out, and buy future problems.

Senator GORTON. Along the same line, you stated that during the post-Apollo debate the White House and Congress rejected the proposal to develop a manned space station and space bases to prepare for lunar and planetary exploration. Can you remember why this proposal was rejected? And do you foresee the proposed space station development as being affected by this same set of reasons?

Dr. LOGSDON. I think the main reason that the proposals were rejected at the time is that they were not in the national interest. I think it was by and large an intelligent decision on the part of the political system not to make another round of major investments in space on anything near the schedule that NASA was proposing.

There was a lot of technological hubris in NASA coming off Apollo in 1969, and not much contact with the reality of national priorities and what the public in this country wanted. There had not been the experience in working in space and seeing what could be done, not the thought on what the potentials were that we have acquired in the last 15 years.

So there really was not a strong basis for an intelligent decision to move ahead. The only reason that could have led to an accelerated and aggressive post-Apollo program is if space continued to be some sort of symbol of competition between the United States and the Soviet Union as it was in the early sixties.

Senator GORTON. We do not lack that base of knowledge now.

Dr. LOGSDON. No, not now. That is why I say I think we are in a much, much better position to take the next relatively small step compared to the grandiose vision that NASA laid out in 1969. Now we have a pretty good sense of things that are worth doing in space and the role of the space station in helping us do them.

Senator GORTON. What do you feel are the international political implications of the proposed space station development?

Dr. LOGSDON. That is an interesting question that I have been thinking about. On one hand, there are lots of strongly nationalistic reasons for going ahead, for exercising U.S. leadership, for pulling ahead U.S. technology, for giving us as a country a sense of common accomplishment. So one could make a plausible argument that this should be a U.S.-only undertaking.

I do not accept that argument. It seems to me that the days of go-it-alone nationalism are really well past, and that the right way to demonstrate U.S. leadership is by bringing along with us our closest allies and those we would like to be allies with in a common

endeavor. So I think the political implications of an international cooperative program are strongly positive and ought to be pursued.

Senator GORTON. If we succeed in the space station, what do you perceive to be the next major step?

Dr. LOGSDON. I would expect the next major step should be developing the full capability to operate between low-Earth and geosynchronous orbit. We do not have that capability now, and I think we are in trouble, as suggested by the recent PAM failures, because we did not invest in the seventies in the reusable transfer vehicle. So I think that is one relatively small addition to the capability.

From what I have read and talked and thought about, it seems to me that the lunar base idea is an attractive next alternative, perhaps a decade from now as we get to this situation again of wanting another major step.

Senator GORTON. In your testimony, you seem to be less than optimistic about the long-term commercial payoff of the proposed space station development. Can you expand on that a little and tell me what your reasoning for that is?

Dr. LOGSDON. I think less than optimistic is more negative than I would say. What I am not is convinced with a high degree of probability that the commercial payoffs are the reason to do the space station. It seems to me it is the test bed where we find out whether the commercial potential is there, but we really have not done the scientific work yet.

It seems remarkable to me that in this period of emphasis on commercialization, the NASA materials science program is actually reducing its budget this year. There is lots of investment to be made in addition to the space station. The space station is an enabling technology to allow us to find out whether this achievement——

Senator GORTON. It is not an end in itself.

Dr. LOGSDON. It is not an end in itself. It is a way to do a lot of different things.

Senator GORTON. You indicated in your testimony that NASA has learned that there is unlikely to be a huge groundswell of public support for an explicit step by step plan leading to a manned mission to Mars or leading to some other distant objective. Would you expand on that a little? Does that mean that you do not think there is public support for that, or only that we can get public support only on each succeeding step?

Dr. LOGSDON. On a step-by-step basis. I cannot conceive of a political leader in the current economic climate saying that we are making this investment in the space station primarily because it will allow us 10 or 20 years down the line to think about manned planetary exploration. It indeed will allow that, but to hold up a manned Mars or even lunar base as the objective now, I think, would not be acceptable to the American people, and if it were the only justification for the program, I would say do not do it. There are enough justifications in terms of science, in terms of applications, in terms of potential of facilitating current applications in space, and when you can add to that that the space station enables us to think, when we want to, of these future steps. That is what adds up to the set of justifications in my mind.

Senator GORTON. Thank you, Doctor.

We now have Senator Heflin with us. Senator Heflin, do you have an opening statement or questions of this witness?

Senator HEFLIN. I put my opening statement at the start of these hearings.

Dr. Logsdon, you seem to be very positive about how this space station decision is proceeding. Would you elaborate some about the Apollo and shuttle decisions, as to how much information was available at the time, and how much opportunity there was for discussion and debate, and what would you say would be the implications of this more open process involving the space station?

Dr. LOGSDON. In terms of Apollo, we were really very early in the space age. We committed to sending men to the moon when our total space flight experience was one 15-minute suborbital flight by Alan Shephard. We were naively optimistic, I think, in terms of what we could accomplish. The country had not thought through—President Eisenhower had not systematically thought through, and Kennedy was new on the job—what we wanted space for.

We were challenged by a Soviet space achievement, and Kennedy decided to respond to that challenge in kind. We chose to go to the Moon, not because of any particular scientific interest in the Moon, but because it was the first spectacular achievement that we could do before the Soviets. It was a race. It was a race that we entered with the intent to win.

All of the thoughts of mission, payoffs, economic benefits, and psychological stimulus that we associate with Apollo were invented after the fact. They were not analyzed. They were not in place at the time the decision was made. So we went really on an adventure, an adventure because we were challenged. It was a very American response.

By contrast, in the 1969 to 1971 period, I think NASA had not done its homework. NASA developed a program that stretched the limits of technological capability without providing a clear rationale of why we wanted to do that.

By going to the moon in the sixties, we did not spend much money or much time in exploring the Earth-oriented scientific applications, or economic aspects of space. NASA needed something to keep it going, and lowered its aspirations bit by bit until it finally found in the shuttle program something that was attractive enough to enough people to provide a major program for the seventies.

NASA, 2 days before the shuttle was approved, went into the White House with a different design. Things were in total flux. Now, here we are, recognizing for at least 2 or 3 years that the space station was what NASA was going to propose. Mr. Beggs at his confirmation hearings in this room said, that is what we are going to do. He set the agency to work in coming forth with a proposal, engaged the contractor base in thinking through missions, payoffs, potential uses, exposed the concept to some very uncongenial audiences, like the Space Science Board.

So, I think that Congress, the Nation, and the White House have a pretty good sense of what is involved as this proposition is being put forth. I think we are in much better shape to make a decision on whether we want to make this investment.

Senator HEFLIN. Thank you.

Senator GORTON. Thank you very much, Doctor. We are delighted to have had your insights into these questions. We appreciate your coming.

Dr. LOGSDON. Thank you.

[The statement follows:]

STATEMENT OF DR. JOHN M. LOGSDON, DIRECTOR, GRADUATE PROGRAM IN SCIENCE, TECHNOLOGY, AND PUBLIC POLICY

I welcome the opportunity to share my views with this Subcommittee on what is a crucially important decision regarding the future of the U.S. space program—whether this country should commit itself now to developing a permanently manned space station in low earth orbit. Only twice before in the twenty-six years since President Eisenhower and the 85th Congress developed the framework for the U.S. space program has there been a similar occasion for a fundamental national decision with respect to that program's future.

One was in 1961, as President John F. Kennedy, only four months after entering the White House, declared it was "time to take longer strides—time for a great new American enterprise—time for this nation to take a clearly leading role in space achievement, which in many ways many hold the key to our future on earth," and that, in order to symbolize this role, "this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

The Kennedy commitment to manned lunar exploration was made in response to Soviet success in orbiting the first human and was developed over a three-week period in consultation with a relatively few individuals in leadership positions. By contrast, the second fundamental decision in the history of the U.S. space program—to develop a partially-reusable space shuttle—emerged from a three-year long, wide-ranging debate over the future of the U.S. space program after Apollo. Early in this three-year debate, the White House and Congress rejected, as not appropriate for the times, a NASA proposal that the U.S. post-Apollo space program should be built around the development of permanently manned space stations and space base in various locations in the Earth-Moon region that the United States should prepare for long duration occupancy of the moon and for manned planetary expeditions in the 1980s. Only the space shuttle, originally conceived as the logistics vehicle for low orbit space stations, proved attractive enough to gain the approval of political, national security, and technological leaders, and at that the decision to proceed with shuttle development was a "close call."

President Richard Nixon's approval of shuttle development on January 5, 1972 was far from another clarion call to space leadership. Rather, it was a minimal decision to develop some new space capability during the 1970s and to keep alive a U.S. manned space program. The alternative to not proceeding with the shuttle was to conduct the U.S. space program with the hardware developed for Apollo and with increased emphasis on automated missions.

Now President Reagan has proposed that Americans "should follow our dreams to distant stars, living and working in space for peaceful economic and social gain," and has called upon NASA "to develop a permanently manned space station—and do it within a decade." You and your fellow members of Congress must decide whether you agree with the President's view that the substantial investment needed to create and exploit this capability is in the national interest, not only this year, but in years to come.

Make no mistake—although almost every year the Congress is asked to approve "new starts" on various space missions and to continue to fund projects already underway, only once every decade or so is it faced with a choice with so much influence on the future of the U.S. space program. Ideally, it would be useful to have a broad national debate over U.S. aspirations with respect to space, but in our system such debates over long-range goals rarely occur, and Congress and the White House, in making year-by-year decisions, set the nation's objectives and priorities. Such decisions should be made in an overall framework, and thus it may be useful to place the current choice in a historical context and to ask how this "occasion for decision" compares with those which led to Apollo and the space shuttle? And, perhaps more important, what is different now?

One thing which is not different is the idea that a permanently manned orbital outpost is a key element in a long range plan for the full exploitation and exploration of space. That notion is as old as the origins of space technology in the earliest years of this century, particularly in Europe, where Tsiolkovsky, Oberth, and von

Braun all identified the multiple advantages of a base in space. The decision to go to the Moon short-circuited early U.S. space station plans, but from the start of the 1960s most NASA planning assumed that a space station was the appropriate post-Apollo goal. In language that sounds rather familiar, NASA head Thomas Paine told Richard Nixon in February 1969 that proceeding with a space station "should not be made to depend on the specific contributions that can be foreseen today. . . . Rather, the justification for the space station is that it is clearly the next major evolutionary step in man's experimentation, use, and conquest of space."

When NASA in 1970 found that it could not gain White House approval for simultaneous development of a space station and a space shuttle, and indeed that it would be fortunate to gain approval for a scaled-down shuttle program, the agency deferred (not abandoned) its station effort and made sure that any shuttle which might be developed could be used in constructing just the kind of modular space station being proposed now. Nothing that has emerged from the results of the Skylab program in 1973, the Soviet *Salyut* program, or the shuttle program since 1981 has changed NASA's conviction that a serious commitment to space will require a space station; thus it really should come as no surprise that NASA once again is proposing that the United States begin to develop one.

I think that NASA must be commended for the way it has gone about laying the basis for a national decision on the space station, especially in comparison to the 1969–1971 period when the organization put forth a rapidly changing series of proposals in response to White House pressures to minimize the space budget. The decision to develop the space shuttle was made without sufficient discussion of its uses or full understanding of its design or costs. Administrator Beggs created the Space Station Task Force in 1982 to develop a space station concept and justification that drew on the full resources of NASA and its industrial and university contractors. NASA has exposed its planning to potential partners in Europe, Canada, and Japan, and to what were likely to be skeptical audiences such as the Space Science Board and the Department of Defense. The result is that, compared to the information available at the time that Apollo and the shuttle were begun, there is now a rich base of experience and thought regarding the proposed space station program.

I must admit to being puzzled by persistent comments that NASA has not spelled out a "vision" of the future into which the space station fits. Anyone who has paid attention to planning for the U.S. space program (or, indeed, for the Soviet space program) would recognize that a space station has historically been seen as the central element which opens up all of space to human activity. The Soviets are already acting on that vision, and have put in place a modest space station with the likelihood that a more ambitious one will soon be available. NASA provided a clear statement of its vision in 1969, when it put forth a strategic plan which, at its most aggressive (and unrealistic), called for:

Space station (earth orbit)—1975; 50-Man space base (earth orbit)—1980; 100-Man space base (earth orbit)—1985; lunar orbiting station—1976; lunar surface base—1978; and initial Mars expedition—1981.

(That plan, incidentally, was presented to this committee's predecessor on August 5, 1969.)

I think you will agree, as Administrator Beggs has said several times, that this is "vision enough for anybody." NASA has learned since 1969 that there is unlikely to be a groundswell of public support for an explicit step-by-step plan leading to early manned missions to Mars—and thus that it is probably not a good idea to state such as the major justification for its current programs. However, there seems to me little doubt that the vision underpinning the specific steps NASA is proposing now is that of increasing man's capability to live and work in space, until ultimately Earth is seen as just the "cradle of mankind." this is obviously an enterprise extending over decades, not years, and one need not totally embrace the vision of human exploration of the solar system to support the incremental steps which have their own justifications, such as the shuttle and station.

Indeed, going ahead with a space station does not mean approving it only as a stepping stone back to the moon and the planets; if that were the only or the primary justification for the effort I would not now be in favor of a decision to proceed with the program. And I do support such a decision, while recognizing that it is still an act of faith in the proposition put forth by President Kennedy in 1961—that "space achievement * * * in many ways may hold the key to our future on earth." That faith is much more solidly based now than it was over two decades ago, but no amount of the experience to date and of before-the-fact mission analysis studies and expressions of commercial or military interest (or non-interest) in a space station can substitute for finding out, by actually trying it, what can be done.

Faith in long-range tangible payoffs is also a weak basis for a multi-billion dollar investment, if it were not accompanied by other, strongly positive reasons for moving forward. Those reasons lie in difficult to measure but nonetheless quite real factors such as: national pride in a shared sense of accomplishment; the impact of major initiatives such as the space station in pulling along with them important areas of U.S. technological capability; the opportunity for engaging our allies in an effort directed toward common human aspirations; and the chance to demonstrate to all in this country and overseas that the United States will not turn its back on the leadership role in space toward which it has already made so many strides.

In the recommendations that formed the basis of Apollo, NASA Administrator James Webb and Secretary of Defense Robert McNamara noted that "it is man, not merely machines, in space that captures the imagination of the world." This observation remains valid today. One symbol to which all in this country and elsewhere respond with a sense of common identification and excitement is visual evidence of human space achievement—man standing on the moon or floating free in space.

While it might be possible to carry out many of the early missions proposed for the space station on an unmanned basis, this excessively rationalist approach denies the psychological, as well as the practical, value of having humans involved. What machines could substitute for Sally Ride as a role model for a young woman considering a scientific career at a time when we need to channel much of our best talent toward such a path?

President Reagan has, in the case of space, acted as a leader should act. In the face of serious disagreements among his advisors over the wisdom of a major new step in space, and recognizing that the case for moving ahead rests largely on intangibles and on a belief, which cannot yet be definitively substantiated, in the important role space achievement will play in the world of 2000 and beyond, the President has challenged you in Congress, and through you the American people, to take the next major step into space.

In the speech announcing his Apollo decision, President Kennedy cautioned the Congress that he was "asking the Congress and the country to accept a firm commitment to a new course of action—a course which will last for many years and carry very heavy costs. . . . If we are to go only halfway, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all." The White House and the Congress did make and honor a commitment to Apollo, and without that commitment it is unlikely the program would have been successful in the face of subsequent criticism and difficulties. By contrast, the White House commitment to the shuttle was weak, and the program was carried out under budget constraints that were a barrier to success in shuttle development and delayed other parts of the NASA program. That should not be allowed to happen as a space station is developed. Hopefully, we have learned from these two experiences: if we are willing to go only halfway, then it is better not to begin. It makes no sense to develop a space station as a center of space activity if we do not also intend to remain active in space.

In 1961, we decided to go to the moon at the very start of the U.S. space program, really without much sense or what such a venture involved and what its long-term impacts might be. (After all, we had only Alan Shepard's 15-minute suborbital flight as our manned space achievement at the time Kennedy announced the Apollo goal.) As a result of the 1969–1971 debate over the post-Apollo space program, the country decided that it did not yet have enough evidence to commit itself of a long-term involvement of substantial scope in space, and we developed the space shuttle because it appeared useful for whatever we might choose to do. Now the country is being asked to approve a next step with multiple uses, but which presumes that space activities will be an important part of the world's agenda in the not-too-distant future. We have 25 years of experience to suggest that perception is well-founded.

I do not envy those who must set priorities and allocate resources among many valuable objectives—yet that is the task of our 537 elected officials. I hope my views are useful as you consider the difficult but exciting choice before you with respect to the space station.

Senator GORTON. We will next hear from OTA, Mr. Rogers, accompanied by Dr. Chandler.

Would they step forward, please?

STATEMENT OF T. F. ROGERS, PROJECT DIRECTOR, CIVILIAN SPACE STATIONS ASSESSMENT, SCIENCE, TECHNOLOGY AND INNOVATION PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY PHILIP P. CHANDLER, DEPUTY DIRECTOR

Mr. ROGERS. Good morning, Mr. Chairman, Senator.

Senator GORTON. Good morning, Mr. Rogers. As is the case with the previous witness, your entire written statement will be included in the record in full. We would appreciate your living up to our 7-minute opening statement limitation today.

Mr. ROGERS. Thank you, Mr. Chairman. We do have an oral statement here that should not take any more than some 6 minutes.

For the moment, let us set aside the expression "the space station." Let us, rather, focus our attention on the long term and fundamental implications of the President's request.

First, we already know what near-Earth space is like. We know how to get there now routinely. We are now contemplating something fundamentally new—the considered development of space. That is, the emplacement of long-term infrastructure there, calling for continued investment commitment.

Second, there is a very wide range of infrastructure options that are available to us, and they imply a corresponding wide range of costs. NASA's current aspirations fall within these ranges, but there are other options that offer mor or less capability at more or less cost. The Congress need not think that the considered development of space stands or falls with NASA's current specific plans, schedules, and costs.

Third, the overall cost to the public to acquire such infrastructure is dependent on factors that should be addressed now: How much capability should we acquire? To what extent should NASA use less costly inhand technology? To what extent will the private sector finance and provide needed space infrastructure? How successful will we be in enlisting substantial cost-sharing with other countries?

Fourth, 25 years into the space age, our Government's near-monopoly on free world space activities is ending. The sooner we face the consequences, the better. Other countries and our private sector will provide important elements of space infrastructure, and we would be surprised if NASA's present plans were carried through without major change.

Fifth, the emerging public discussion of a so-called "civilian space station" is forcing us to reexamine the Nation's overall posture in space: How should we acquire and pay for large-scale, long-term space goods and services? Are the established traditions of cooperation with other countries adequate to the times? What is the influence of our burgeoning military space program? Above all, what are the goals and objectives for our publicly supported civilian "space station"?

Let me now turn to two matters of particular interest to your committee. First, "smart people and smart machines". At this point, across-the-board pronouncements are unwarranted, but

today cost-conscious, case-by-case decisions should reflect the following considerations.

Unforeseen circumstances are bound to arise in space, and people there could deal with them promptly and effectively. Sophisticated machines in concert with people should be employed for ongoing R&D and commercial-industrial operations. And machines should do essentially all long term repetitive and particularly hazardous work.

Let me point out, however, that these activities have to do with work. As the development of space expands, human cultural activities are bound to follow, and to carry out those successfully requires that questions relating to long-term human survival and functioning in space be answered by a study of human beings there.

The second, international cooperation. When measured in dollars, space cooperative arrangements to date have been relatively limited. Spacelab is the exception that proves the rule.

Now, many friendly countries have demonstrated substantial space capabilities. They desire to work with us. But in any future cost-sharing cooperative agreements, we must be prepared now to treat these countries as true collaborators.

Senator Gorton, our fundamental observation at this time is this: Space infrastructure is methods and means, not an end in itself—not an end in itself. Consequently, we ask: Does our civilian space program really have appropriate contemporary goals and objectives against which NASA's proposed infrastructure can be usefully measured? Goals and objectives that command mainstream, continuing public attention? That have great humanitarian as well as scientific value? That foster the development of "cutting edge" technology? That have relevance to global public issues? That prompt major international cooperation? That invite major private-sector participation so as to advance our economic prospects?

We think not yet. And therefore we conclude that it is impossible to judge objectively whether or not NASA's currently favored infrastructure elements are truly appropriate and worth their substantial public cost.

The United States, Mr. Chairman, can now do anything that it seriously wants to do in space. We must be clearer on what we want to do and why. Only then can we best determine how.

Thank you. That is the end of our oral statement.

Senator GORTON. What policy implications are there if we were to accept that conclusion on your part?

Mr. ROGERS. From the viewpoint of the Congress, it would suggest to us that the executive branch be given every encouragement over the next year or two, while they are proceeding with whatever you judge they should be doing of an engineering nature with respect to this infrastructure, to think out again, broadly, with the broadest public participation and professional participation that they can prompt, to think out again where this country should be going in the civilian space area.

Senator GORTON. But it would not be a consequence that we should delay for another year or two the initial authorization?

Mr. ROGERS. Oh, no. The future is always the enemy of the present, Mr. Chairman. And we do not suggest for a moment, we would not want to be thought of as suggesting that.

The President could not have done it better. He said "a permanent presence". He used the expression "space station," but he said "a space station," not "the space station." He said a decade, and he said, let us start sensibly and slowly, at a level of $150 million. I do not think in any sense he could have said it any better.

It not only—because of the great breadth that he encompassed in his remarks about the goals in the space area, this prompts, indeed demands, a national debate. And he, by the very words that he chose and by the very request of the Congress, has seen that the time and flexibility is available for so doing.

Senator GORTON. You mentioned that the implementation of automation in space is not encumbered by what you call the institutional constraints which confront the introduction of automation here on Earth. Would you describe what you believe those institutional constraints to be and why we are free of them as we go to space?

Mr. ROGERS. Well, there is one interval in my professional career that you might not be familiar with, Senator. I was the first Director of Research in the Department of Housing and Urban Development. And I had come from the two great—I will not say greatest, but the two great—technologically sophisticated groups of the country, MIT and the Department of Defense, and I set about imagining how one might construct experiments dealing with problems and opportunities in the cities and in housing.

And did I "get worked over." I found that trying to put together even experiments in situations outside of the laboratory, let alone trying to introduce the fruits of scientific inquiries, into the way that people designed and built cities and the infrastructure supporting them and the housing industry was unimaginably complex and sensitive.

So what we have in space is an opportunity to conduct very broad and very advanced scientific inquiry and technological demonstrations, without having to be concerned about prices and wages and contractual agreements, you know, the hundreds of things that simply amount to great R&D programmatic viscosity here on Earth.

Senator GORTON. One of the space station cost drivers you mentioned is the extent to which new technology is implemented against technology which has been tested and used over an extended period of time. To what extent should we use newer technologies that will not have to be replaced so quickly, but the capacities of which would be more responsive years after their implementation? Or how do we make those decisions?

Mr. ROGERS. Old technology does not necessarily have to be replaced very quickly. My experience is that the first equipments to get replaced are the new ones, while you pull them back out and find out why it is they do not understand the theory.

We observe that NASA set about considering the question of whether or not there should be a lot of new technology with the presumption—that is in the record—the presumption that there

would be a great deal of new technology. Now, we think, for two reasons, one should be very cautious about this.

One is that the country already has made a very, very great investment in the development of a great deal of sophisticated and workable technology. More important perhaps than that: NASA has done an outstanding job of building a very sophisticated space industry. These people now know how to go about building things that even a decade ago they could not.

They want the opportunity to be given, by NASA, performance specifications for things to be put in place and then to be charged by NASA to get the unit costs down as far as possible, so that the technology that is developed is the lowest cost to the public sector and takes the best advantage of what the industry can do the best, pay attention to the bottom line as they are developing goods and services.

What this does is to give you a very objective dividing line that you can work with. What industry now can produce at a lower cost, let them do it; and what they cannot, that NASA still needs, let that be the driving point for the new technology. And we would say further that whatever moneys then are saved, and more particularly whatever talents, professional and management talents, are saved, could then be put on to truly cutting edge advanced technology activities which the industry cannot mount.

That is our sense.

Senator GORTON. Another cost driver you mentioned is the extent that military technologies may develop. But DOD has said it has not identified any military space activities at this point. Do you foresee that DOD will maintain this position of noninvolvement, and if not to what extent do you foresee a space station becoming more involved with questions of national defense?

Mr. ROGERS. There is no OTA view on this at the moment. We have been looking into those questions, but when the President made his speech a year ago dealing with ballistic missile defense, it was very clear to us, immediately, that this was a matter that was going to touch everything that the Department of Defense space-related strategic, support, and tactical forces would have to deal with.

We decided then to step back and wait and see. It is clear that there will be one particular fact, unless we are more fortunate than we usually are. That is, if one builds a very large military program rapidly—if one makes a rapidly increasing demand upon the professional and industrial people of the space area beyond what present capacities allow and at the same time start a major new infrastructure program on the civil side, we will see unit costs rise.

The first thing that will happen is that prices will go up. Beyond that, it is difficult immediately to say about the Department of Defense. I think that there will be two things that they will do fairly soon. Exactly how they will do it with respect to the infrastructure that NASA is thinking about is not clear.

But one, that they will start to do a lot more basic and applied research up there with their own people and their own perspective, their own values, their own operational sense. And the second thing, they will begin to take advantage of either extended shuttle

lifetime, extended shuttle capabilities, or servicing capabilities to try to contain the costs of their support equipment up there. I think they will learn how to do that effectively.

Senator GORTON. Thank you.

Of the three options you mentioned for international participation, one is a multinational program or consortium; the others consist of various bilateral developments, which you say is closest to the traditional practice. What is your view of the advantages and disadvantages of these ways of engaging in international cooperation?

Mr. ROGERS. John Logsdon used the word "visions." We all have visions. One vision that one could have here is that of the United States striding out and leading an orchestration of the interests and the activities and the capabilities of all of the nations of the World that would join freely with us. That calls then for a very, very broad arrangement, and that of course is very, very difficult in the doing.

But it can be done. We have, certainly in both Intelsat and Inmarsat and some of the commercial aviation areas, we have examples that that can be done. Large numbers of countries can conclude it is in their better interest to cost share and operate share and so on.

And perhaps—in the longer run, I think to the extent that the United States would want to be the true leader of an international orchestration—that would be a fine goal. I think in the meantime, since we have done so little of this of a major nature in the space area, attempting to reach agreements with individual countries or smaller groupings of countries should be encouraged, because we are convinced that the climate out there right now is going to be different, in many ways more difficult, although in the longer run more healthy. We are going to have to deal with a lot more experienced people there. They are going to see their own national interests differently than we see our national interests.

The space business is coming to an international maturity here, and perhaps NASA's working with a handful of countries to begin with to learn this is indicated.

Senator GORTON. Thank you. I will defer to Senator Heflin.

Senator HEFLIN. The President's request this next fiscal year of $150 million is sort of a beginning of the $8 billion total cost. It is, of course, starting out in the definition stage.

Based on your analysis and best thinking, what guidance should Congress provide for how the money should be spent and how NASA should manage the program?

Mr. ROGERS. Let me take up the last words first, Senator, the matter of management. It is always a difficult thing, I think, for a board of directors, as I see the Congress with respect to the executive branch, to get into much detail in the management area. But not to look at it at all sometimes allows excesses to develop.

We have thought about this quite hard. We conducted a workshop, a 2-day workshop in which we brought people from the space industry, both those working directly with the Government and on the commercial side. Many of the members of the workshop were former, very senior NASA people, and we are in the process of turning out about a 10- or 12-page paper on that.

I might say that it was a very sensitive matter, Senator Heflin. We did not find it easy to obtain people who would be not only smart, objective, but also willing to speak to this, but we did. And we will be pleased to forward that to you very soon. I think you will find that a useful piece of paper.

But let me answer more generally about costs and about management. The people in the space station task group that we have met are clearly superior professional space engineers. They are smart, they are responsible, they are hard working, and they will do what they know how to do very well.

There are, though, two other questions that arise, and one is, should they still be doing things today the way they did in the past? Twenty-five years is a long time. We have been at this building of civilian and space capability now for well over a quarter of a century. I would repeat, of the many things that NASA had to do, and did well, but today they may not be taking the best advantage of, is that they helped to build an extraordinarily accomplished and sophisticated space industry.

These industrial people are very, very smart. They are very, very tough minded. They would love to get their hands on the way that a lot of this infrastructure could be built and do it their way. They can see a great many different ways by which the unit cost—not the total cost, because that depends on how much you want to buy, but the unit cost—could be much better contained and reduced.

So I think one of the challenges to NASA is to reexamine how it is that they are relating to the space industry, how they are using the space industry, and asking whether they are getting the most out of it. Are they challenging them the most, are they leaning on them the most to think, to innovate, to come back with new ways of doing business, not only in the space station area.

There are things which people working in the space station cannot touch on easily. Let me give you a specific example. We talk about cost sharing with foreign countries and we have said in our statement that it is impossible at this moment to make sharp estimates of what the cost of the infrastructure will be to the Federal government. It could go up or it could come down. It is a very slippery number at this point.

One reason is that we do not know how many countries will join with the United States in the development, in the operation, in the use, of the space infrastructure, and not only share the benefits but share the costs. Now, let us suppose for the purpose of discussion that it turns out that countries will agree to underwrite the development of 2 billion dollars worth.

Now, what do you think NASA will do at this point? Will they come back and tell you—will they be pleased to come back and tell you 2 years from now that "the cost of the space station" is down, that the cost to the taxpayer has been reduced by $2 billion? Or will they say, now there is another $2 billion that can be put into additional infrastructure?

There is not much that the task force engineers or the space station engineers will have to say about that, but there is a great deal that you can say about that.

Senator HEFLIN. In the definition stage as you have developed it, what would be the problems and the costs of funding alternate al-

ternatives? You have listed in your testimony several different alternatives, some less costly than some others. As you proceed with the area, with the possibility of there being some change at a later date, what are the problems and costs of the definitions of alternatives, as well as the NASA proposal?

Mr. ROGERS. Well, I do think this, Senator. You do have to have a zero-order, a fairly broad, sense of what the total is that you want, and you have to have some sort of a zero-order plan for getting there from here.

But you should be somewhat humble. You know, we all make mistakes. We make new discoveries. For instance, one can look back at maps of Washington and see how things have changed here, even in a decade, you can see changes in a city. You do not see them in a year, but you see them in this city over a decade.

Different events come forth, surprises take place. The amounts of money available, the amount of talent. So you should be a little bit humble, and you have the particular advantage here that you are dealing with infrastructure which is quite different fundamentally from, let's say, an aircraft. NASA could not, for instance, have decided in midstream in the shuttle program to leave off the wings. They cannot do that. It will not fly, or at least it will not land safely.

But in the matter of the infrastructure, for instance, you could do a very great deal of what you want to do up there with, say, 10 kilowatts of power. Of course, the power in space is thousands, perhaps as much as $10,000 a watt. It is one of the great cost drivers.

You could plan that infrastructure in such a fashion that you put in 10 kilowatts to begin with and then, as perhaps the industrial and commercial demands for more arose, add another 10 kilowatts a few years later on. You could plan for that. You need not have all of the plans implemented on an all-up, first-cost basis immediately.

That is one very important message that we are giving you. It is an important flexibility in this infrastructure acquisition area that you do not have in many other areas.

Does that help you, Senator Heflin?

Senator HEFLIN. A little bit.

Thank you.

Senator GORTON. Mr. Rogers, thank you very much. We appreciate your being here.

Mr. ROGERS. Thank you.

[The statement follows:]

STATEMENT OF T. F. ROGERS, PROJECT DIRECTOR, CIVILIAN SPACE STATIONS ASSESSMENT, SCIENCE, TECHNOLOGY AND INNOVATION PROGRAM, OFFICE OF TECHNOLOGY ASSESSMENT

The Office of Technology Assessment (OTA) is pleased to be offered this further opportunity to testify before you today on the subject of the publicly-supported civilian space program, and especially on "Civilian Space Stations."

I am T. F. Rogers, the Director of the OTA Civilian Space Stations assessment. I am accompanied by Dr. Philip Chandler, the Deputy Director.

Since appearing before you some three and one-half months ago, OTA has issued its first assessment report, a Technical Memorandum: "Salyut—Soviet Steps Toward Permanent Human Presence in Space." And the President has directed NASA to develop a space station, and he has asked the Congress for authorization and appropriations to begin to do so.

Also, our continuing studies have given us an even clearer sense of the issues involved in this area, options available to the Congress in the light of this Presidential request, and those issues of particular interest to the Committee.

INTRODUCTION

Let me underscore at the outset that OTA does not take a position on the desirability of any "space station." We do observe, however, that Americans will continue to go into space on the Shuttle and that the number of elements of space infrastructure will increase. The primary focus of our assessment, therefore, is not whether a "space station" should be built, but what are the issues and options regarding the acquisition of additional capability for exploring and exploiting space.

At present, NASA appears to favor a large and sophisticated ensemble of elements, employing a great deal of new technology and capable of supporting a fairly large human work crew, and apparently favors procuring it in what might be described as the "classical" NASA fashion. In round numbers, NASA now estimates that the infrastructure's initial cost to the Federal Government could approach $10 billion over the next 7-8 years, with the total cost approaching $20 billion by the end of the century. It seems to be in the nature of things today that, given the way that the Government acquires new high technology space assets, the ultimate capital cost usually exceeds initial estimates, often by large amounts.

On the other hand, the circumstances under which any such infrastructure would be acquired are unusually dynamic. The Department of Transportation has entered the civilian space area; the interest of our commercial-industrial sectors in the private development and provision of space infrastructure assets and services is growing; and some infrastructure. It should not be surprising, therefore, if the *net* cost to the United States Government for all of the infrastructure NASA currently envisions were to be significantly less than these figures.

INFRASTRUCTURE OPTIONS

As Congress addresses this matter, it is fundamental to their consideration of the issues that they appreciate that there is now *no* single thing that can be called "The" space station. There are, rather, a large number of potential "space stations" that could be made up of various combinations of such characteristics as:

On-orbit lifetime; volume; power; communications; and local transportation.

In our previous appearance before you, we provided you with a listing of some combinations of infrastructure element characteristics, the suggested needs which these applications could meet, their capital cost, and the time that it should take to obtain them. We have made a few modifications to this listing, and our up-dated version accompanies our written testimony.

Let me give you three examples of the kinds of arrays of infrastructure that could be obtained. (While these examples are not to be found, as such, in the attached tables, they draw upon the information contained therein.) I present them in the order of the increasing capability that they could provide, and of their increasing associated costs.

(a) An Orbiter, capable of supporting, comfortably, as many as 4-6 people, and with its allowable in-orbit staytime extended to, say, 3 weeks; plus two modestly powered freeflying platforms, with modest communications, and without crews, one in polar orbit, one low inclination orbit, both capable of being leased from the private sector and periodically tended by Orbiter crews; plus a so-called orbital maneuvering vehicle (OMV) that could move back and forth between the Orbiter and freeflyers at other altitudes. This kind and amount of infrastructure would allow a very great deal of the kinds of scientific experimentation of currently identified interest, and the servicing of freeflyers as well. This is a "relatively lower cost" option.

(b) The same as (a), but with the extended lifetime of the Orbiter supplemented, or replaced, by a permanent in-orbit facility having wide-band communications, 10-15 kilowatts of power, and able to support a human crew of 4-6 persons. This would allow long-term experiments using human beings as subjects or requiring in situ human attendance not possible with the Orbiter—the kind of experiments of particular interest in the life and materials sciences. This is a "relatively modest cost" option. This particular array of elements would provide capabilities substantially greater than those provided by the Soviet Union's present space infrastructure.

(c) The same as (b), but with the addition of a reusable orbital transfer vehicle (ROTV) designed to move back and forth between its service module in low Earth orbit (LEO) and geostationary orbit (GEO). This addition would allow the possibility of servicing and modifying spacecraft in that 22,000-mile orbit, and could lay the

basis for more efficient transportation between the Earth and the moon and the planets. This is a "relatively higher-cost" option.

Please note that these examples are not to be taken as recommendations; I have given them to you simply to illustrate that there is a wide variety of infrastructure elements and capabilities to choose from—and a correspondingly wide range of costs. The costs implied here cover a range of some ten-fold. In any of the examples, the direct cost to the Federal Government could be kept to a minimum by making good use of already developed technology; keeping modifications thereto to a reasonable minimum; employing modern, cost-conscious, commerical-like acquisition practices; and cost sharing with other countries as well as, it is to be hoped, our private sector. Certainly, very useful capabilities can be obtained from infrastructure elements at costs to the Federal Government well less than those which NASA is now considering—and, of course, even greater capabilities at greater cost.

In any case, there are likely to be cost-offsetting advantages in obtaining some carefully chosen ensemble of infrastructure elements: space transportation to and beyond LEO could become more efficient; equipment on board and in freeflyers could be serviced and modified; experiments might be conducted more rapidly and efficiently; the private sector and other governments could be expected to pay for the use of its services; and important "spin-offs" should be achieved. While it is not now possible to estimate the magnitude or time of attainment of these advantages, they could be considerable.

"SMART PEOPLE AND SMART MACHINES"

At present, humans generally surpass artificial intelligence and robotic technology in performing intellectual and physical work that requires creativity, versatility, and flexibility. And, unlike earlier space days, people can now be transported to space routinely and employed there in a wide variety of tasks, both within and external to in-orbit space facilities. However, insofar as memory capacity, computing ability, strength, endurance, and particularly working at long-term repetitive tasks, machines often surpass humans.

In view of their relative strengths, and setting aside any considerations of the intangible value of our having some of our men and women in space, the most practical way to arrive at decisions re the selection of "smart people" and "smart machines" is simply to make careful and comprehensive estimations of the marginal cost of employing each, and the value of such employment to the work to be accomplished.

There is no general conclusion that can be arrived at today in this regard—decisions will have to be made on a case-by-case basis. But a general continuum can be outlined:

People should be employed to deal with unkown circumstances and "surprises";

People should be assisted by machines to gain speed, strength, and memory, and to improve their sight and other senses, and their mobility; and to be provided with artificial senses via radar, lidar, radiation detection, etc.;

Machines, aided by people, should be employed for ongoing R&D and commercial-industrial operations; and

Machines, maintained by people or not as circumstances suggest, should do essentially all very long-term, repetitive work.

And, of course, people and machines in space can be connected directly and quickly with machines and people at the Earth's surface via radio communications circuits so as to make the best use of both environments.

It should be appreciated that this is the current situation. Human beings will gradually become more proficient at working in the absence of both gravity and an atmosphere, and the tools provided them will increase their effectiveness in space. Even so, given sufficient support of appropriate research and development activities during the next few decades for robberies, artificial intelligence and combinations of the two, it is reasonable to expect that "smart machines" could gradually replace "smart people" for many, perhaps most, in-space work tasks.

Indeed, advancement of the field of automation generally, including the related fields of artificial intelligence, robotics, telepresence and teleoperation, could be considered as one of the important objectives of a civilian space program, rather than a side benefit in the pursuit of other goals. For there are two important advantages to the conduct of such novel activities in space: (1) few, if any, of the institutional constraints that confront the introduction of automation here on Earth should be present in space, at least for awhile, and (2) the lessons to be learned by their conduct will receive a great deal of publicity, thereby prompting a more rapid practical use thereof.

Finally, however, we should not forget that carrying our physical work is not the only thing that men and women do. As we continue to exploit, and to develop, near-Earth space, circumstances are likely to arise that suggest the conduct of activities of a more broadly cultural nature as well. One of the challenges of our civilian space program could be to develop ways by which, in time, some of us can visit space.

INTERNATIONAL COOPERATION

As one of the objectives of the U.S. publicly-sponsored civilian space program, the National Aeronautics and Space Act of 1958 cites "cooperation by the United States with other nations in work done pursuant to the Act and in the peaceful applications thereof." This is the foundation in law of the longstanding NASA tradition of international cooperation.

Proponents of international cooperation in civilian space activities suggest at least three advantages: 1) cost savings to the U.S. taxpayer may be achieved; 2) all participants will benefit from a sharing of information and experience; and 3) U.S. foreign policy interests are thereby promoted. U.S. opponents of such cooperation tend to focus their arguments on the hazards of technology transfer, judging that the United States almost always appears to give away more than is returned, and opponents in other countries bridle at any continued "subservience" to other than their own perceived national interests. In general it may be said that the nearer the cooperative activities are to basic research, the fewer the difficulties in agreeing on satisfactory cooperative arrangements; the nearer such activities are to commercial "payoff", the more difficult it is to establish such arrangements. Thus, the two major limitations on international cooperation are (a) a national desire to "go it alone" and (b) potential or real economic competition resulting from the cooperative activities.

When measured in economic, and not rhetorical or other intangible terms, the cooperative space arrangements to date have been relatively limited: with the sole exception of the ESA Spacelab program they have been of little financial consequence when measured against NASA's expenditures. But times have changed: ESA, some individual ESA countries (notably France, the FRG, and Italy), Japan, and India have now demonstrated substantial space capabilities and show a keen interest in developing more. And, under appropriate circumstances, cooperation with such other countries as the U.S.S.R. and the P.R.C., could be envisioned. Thus, with the advent of any "space station" program and, more particularly, the President's specific call for substantial international cooperation therein, we should reconsider the options de novo. There are three major alternatives, for each of which there are advantages and disadvantages.

The first option could be to reject international cooperation in any "space station" program altogether—or to pursue it with such little vigor and imagination as to have essentially the same effect. To take this course would be to break radically with the past and to ignore the President's "judgment call," and would, therefore, call for particularly careful scrutiny.

The second option could be some form of multi-national program, perhaps undertaken from the beginning by an independent multi-country space agency (possibly formed along the lines of the European Space Agency), or perhaps taken over sometime after its U.S. inception by a multi-country consortium on the model of Intelsat or Inmarsat. Adoption of this course could be guided by successful precedents, but would, nevertheless, result in a substantial change in current practice.

The third option could be a U.S. program with various forms of bi-lateral involvement. Although this course is the closest to traditional practice, there are a number of alternatives for substantially increasing collaboration with other countries in the program, either in the development stage, in the operational stage, or both.

COST DRIVERS

Let me now turn to the matter of costs generally.

Beyond the observation that, in some general fashion, the cost will increase with the generality and sophistication of the space capability acquired, it is difficult—indeed, in our view, it is impossible, at this time—to estimate the eventual cost of the infrastructure capability to the Federal Government. Let me observe that at least all of the following factors (and, presumably, some others we have not considered) could have an important influence on this cost:

(a) the total capability acquired—which, as suggested by the examples I have just given, can encompass a considerable range;

(b) the extent to which already developed, tested, and paid-for technology is used, vs a focus on new technology with its higher development cost and greater risk of cost overruns;

(c) the substitution, where feasible, of automated systems for the accomplishment of tasks previously undertaken only by human beings;

(d) the manner by which the infrastructure is acquired, i.e., the extent to which NASA puts the engineering challenge on the space industry by issuing performance specifications, rather than continuing to issue detailed engineering specifications and managing the acquisition process in detail;

(e) the extent to which a large and rapid expansion of military space research, development, test, and evaluation (RDT&E) activities increases costs in the civilian space sector also;

(f) the extent to which any "Christmas-tree effect" takes place within NASA, whereby the infrastructure acquisition management is persuaded by the NASA Centers to allow the cost of desirable but non-essential RDT&E activities to be charged to the acquisition program;

(g) the effectiveness of NASA's efforts to persuade our private sector to develop infrastructure assets and services "on their own," and to provide them to the Government at purchase (or lease) prices lower than those achievable by the Government;

(h) the effectiveness of NASA's efforts to effect eventual private-sector operation of the infrastructure and its related activities;

(i) the effectiveness of NASA's efforts to arrive at large-scale collaboration and related cost-sharing arrangements with other countries; and

(j) whether or not NASA moves, seriously, to protect the in-orbit infrastructure against physical attack.

Finally, inasmuch as there is no objective, urgent, external demand to obtain such an infrastructure (as we point out in the next section), an approximate average annual expenditure rate could be set for so doing, so as not to burden the budget excessively in any one year.

Thus there are a number of factors that could influence the net cost to the taxpayer for requiring space infrastructure, and many opportunities to minimize this net cost that could be grasped by vigorous and imaginative NASA management, i.e., by bringing about the "cultural change" that some NASA leaders have recently called for.

I want to remind you that we are discussing today only the initial capital cost of this infrastructure—(O&M) costs; the cost of instruments, furnaces, etc., needed for scientific experimentation in association with its use; and the interest cost of any money borrowed to fund the acquisition program. Remember, too, that the infrastructure will eventually wear out.

These considerations suggest that, over the next year or two, at least as much attention should be given to identifying better processes by which the country sets about the permanent development of space as there is given to any physical characteristics and capabilities that are to be obtained.

In this regard, it is important to note the specific words used by the President in January when he directed NASA to develop a "space station" and requested the Congress to authorize and appropriate funds to begin. He did not say the "space station"—he said a "space station"; he allowed a full decade for its development; so far he has asked for less than 2 cents on the dollar of NASA's estimated initial operating capability (IOC) cost; he invited the active participation of other countries; and he envisaged a substantial potential for space commercialization in relationship to it. These steps allow adequate time, and sufficient flexibility, for careful evaluation of the most important uses to which any space infrastructure would be put; the kind and the amount needed, by when; how it should be procured; who should pay for it; and who should operate and use it.

Most importantly, they allow time for a national debate on the subject of appropriate, broad goals and objectives for space—goals and objectives that would respond not only to the ends of science and exploration but to more general cultural, economic, and political ends as well.

GOALS AND OBJECTIVES

Mr. Chairman, it is very important to appreciate that space infrastructure is simply that—infrastructure. Its availability would presumably allow certain new space-related goals to be addresed and objectives to be accomplished. But it would only be a "stepping stone" to the achievement of objective ends. The President stressed this point by saying: "But most importantly . . . a space station will not be

an end in itself . . ." and he stated that the country should reach for ". . . exciting goals in space . . .".

The civilian space-related goals and objectives of the United States should be such as to command widespread attention; have great inherent humanitarian and scientific interest; foster the development of new technology; have relevance to global issues; prompt international cooperation; and involve major participation of our private sector so as to advance our economic prospects. But over the past decade the government has not studied and articulated such a national agenda of goals and objectives. And to state that the infrastructure, or "space station," could serve 107 different uses, or interests, as NASA has done, does not provide us with the kind of crisp, objective, persuasive end uses that we should see advanced in explanation for the expenditure of the great sums and the use of the outstanding talents called for here.

In the absence of such goals and objectives, and with the great uncertainties in the estimate of any infrastructure cost to the public, OTA concludes that it is simply not yet possible to judge, objectively, whether or not NASA's presently suggested infrastructure elements are truly appropriate and worth their substantial cost.

Furthermore—and OTA has been making this point for over a year—we know of no broad and continuing professional study effort which could be used by our national leaders to see that the American public has the opportunity to consider and help initiate space-related activities that address important cultural, economic, social, and political ends. We are pleased to note that Dr. Keyworth spoke to this important matter in testifying last month before the House Subcommittee that deals with NASA Appropriations.

A successful National Commission on Space could go far toward calling widespread attention to our civil space problems and opportunities. It could give broad public consideration to our national interests here—consideration that would encompass interests beyond those of science and technology that receive by far most of the attention today. Anticipating that it could help in the national debate that the President's decision and challenges call for, OTA is giving this possibility careful thought, and we will speak to it in our final report, which we hope to complete this spring.

The President's request for another large and eventually costly public space program should not prompt, indeed it now requires, a national dialogue about United States interests and purposes in the civilian space area. Our great investment in space—to date, over $200 billion (1984)—has already positioned the United States to do almost anything that it seriously wishes to do in and with respect to space, and there are many promising opportunities to do so. What is now needed is, to use NASA's own expression: ". . . the revitalization of the nation's space program . . .", and a determination to understand that the nation's civilian space interests are now broader than our government's civilian space program.

Such a debate is prompted not only by NASA's presently expressed aspirations, but by military, other-country, and private-sector developments and considerations as well. All of these sectors of our society, our universities, and particularly interested sectors of the general public, should now move to participate in this debate.

Whatever the judgement of the Congress is regarding the Administration's request for studies of defining the desired space infrastructure over the next two years, this time certainly should be used by both Congress and the Administration to see that the United States now decides upon and articulates again, in contemporary terms, its civilian space goals and objectives. And NASA should be encouraged to consider trading off any Government effort and cost reductions below their present aspirations in the "space station" area with other new and imaginative space activities that would require the development of truly "cutting-edge" technology.

As we now move beyond the initial exploratory period of space activities and approach the considered development of space, we should be careful, above all else, that we not get caught up in either fascination with or the details of exotic space technology. What these times call for is not so much technical expertise—we have that in abundance—but, rather, vision, wisdom, judgment, and leadership. We should all now focus on sensible and generally acceptable methods whereby we can indeed develop America's next frontier, meet human needs in so doing, and fashion new ways of paying for it as we go.

SUMMARY

Top recapitulate briefly, Mr. Chairman, in our judgement new forces emerging here and abroad, in both government and private sectors, will have an important influence upon the way by which any space infrastructure acquisition program develops over the next very few years, and the public cost of this program. Indeed, we would be surprised if NASA's present "space station" plans were carried through to completion without major change.

And the energetic study, growing public discussion and, now, Presidential support of a "civilian space station can serve a very useful purpose that transcends consideration of any station itself.

It is forcing us to re-examine our civilian space experience, institutions, and physical assets; our manner of acquiring, paying for and using these assets to provide large-scale useful goods and services; and the influence of the space interests of other countries, and of our own private and military sectors, upon our publicly funded civilian space activities.

Today, we have far too narrow and fuzzy a vision of our prospects in the space area. Without a clearer, more thoughtful, vision, how can we expect consensus on our objectives? And without consensus, how can we rationally make long-term public commitments? Arriving at such a consensus over the next two years should be our first order of business.

Mr. Chairman, Thank you for inviting us here today. I trust that the completed OTA assessment, which will speak directly to all of the matters I have mentioned here, will be useful to the Committee when it is available a few months ahead.

Attachment.

ALTERNATIVE APPROACHES FOR REALIZING SPACE INFRASTRUCTURE

The accompanying Tables are designed to assist in evaluating alternative approaches for obtaining space infrastructure that could, in varying degree, satisfy various needs or requirements that have been expressed for such infrastructure. The Tables include those elements of a so-called civilian space station as now generally envisioned in NASA planning.

Typical options (of the many that could be examined) are shown in Table 1 for three groups of possibilities. First, the present Shuttle Orbiter and its possible modifications for extended stays on orbit (Extended Duration Orbiter—EDO) are listed. Second, one version of the Spacelab developed as a free-flying inhabited core vehicle is examined. Finally, the present NASA-envisioned space station concept is given: both the initial operational capability (IC) version (~1992) and a mature, fully-developed infrastructure (~2000).

The parameters for each option that may be used for rough comparative purposes are:

1. Approximate date of availability, assuming that a "go-ahead" were given in 1985;

2. Cost (in fiscal year 1984 dollars) to produce the capabilities shown. Some options depend on existing hardware so the costs do not reflect similar proportions of development and production efforts for the various options;

3. Characteristics—several design parameters and sizing factors that provide the bases for infrastructure capabilities;

4. Capabilities—the types of functional activities that the listed infrastructure should be capable of supporting, and the degree to which these activities mighe be accomplished;

5. Responsiveness of a given infrastructure to the various reasons put forward for having a "civilian space station," including any extended presence of human beings in space.

If great and long-range space activities (such as say, for instance, the establishment of a lunar human settlement or the return of materials from the asteroids or Mars) come under consideration, they would appear to be achievable using a sophisticated orbital transfer vehicle coupled with on-orbit assembly, check-out, launch, and recovery. The one option listed in Table 1 with some of these capabilities is the NASA fully developed infrastructure.

Table 2 presents information on proposed "free-flyer" space platforms that could be used in conjunction with, and serviced by, any of the options listed in Table 1. In this way, additional capabilities could be added to the infrastructures given in Table 1 for the cost of buying and incorporating these platforms in the overall infrastructure.

Interest within the private sector indicates that it may be able to provide some of the platform elements of a space infrastructure; in Table 2, both MESA and LEASE-

CRAFT are proposals of United States aerospace companies (Boeing Aerospace Company and Fairchild Space Company, respectively). Among others, a new private enterprise, Space Industries, Inc., is studying a module that would be a long-duration industrial facility suitable for manufacturing (materials processing) in space. While it is too early for details of design and cost to have been revealed by the company, the module apparently would be tended by a crew while the Shuttle was in its vicinity. As with the others, it could be in place prior to the planned installation of the NASA-proposed space infrastructure. In addition, both Teledyne-Brown and Ball Aerospace Systems are studying the possibility of providing facilities that would be mounted in the Shuttle's cargo bay and used for experiments. And several space organizations are giving active consideration to provide development of large, in-orbit power supplies.

Another alternative not specifically listed in the tables is the use of the Shuttle external tank (ET) as an infrastructure component. Conceivably, the ET could be used for fuel and materials storage, as a pressurized module, for mechanical structure, and as a safe haven during emergencies. A principal advantage is the low in-orbit cost. Relative to the other alternatives, it has received modest study and is therefore mentioned here only.

Some cautions should be noted in the interpretation of this information. These are preliminary descriptions of the options and estimates of their capabilities. All estimates are given to an order of magnitude. Capabilities have been described by qualitative adjectives; quantitative descriptions would be premature at present. In the fifth section, in response to the reasons advanced for a space infrastructure, the comparisons are qualitative and subjective in nature and are presented simply to bring these factors to the attention of the reader. Future revision is possible as issues become more sharply focussed and designs are given more study. For instance, as a particular item the Spacelab option of Table 1 is only one of several that hae been put forward; one by European Space Agency (ESA) countries could definitely augment international cooperation if it were to be implemented.

TABLE 1.—COMPARISON OF SOME OPTIONS FOR EARTH ORBIT INDEPENDENTLY OPERATING INFRASTRUCTURE

System	Shuttle orbiter	Extended duration orbiter: Phase I	Extended duration orbiter: Phase II	Spacelab (developed as permanent infrastructure)	NASA infrastructure aspirations	
					Initial operational capability	Mature, fully developed
Date available: Now, or approximate, assuming start in 1985	Now	1988	1990	1990	1992	1996–2000.
Cost: (billions of fiscal year 1984 dollars)	None	0.1	0.4	2	8	20.
Characteristics:						
Power to users (kW)	7	7 [1]	20	6	90	200.
Pressurized volume (ft [3])	2,000	2,000	5,000 [2]	5,000	6,000	10,000.
Crew size	5	5	5	3	8	20.
Miscellaneous	Can accept spacelab	No new technology	New technology required [3].	Limited crew accommodations.	Orbital maneuvering vehicle [4].	Reusable orbital.[5]
Capabilities:						
Time on orbit	10 days	20 days	50 days	Unlimited [6]	Unlimited [7]	Unlimited.[7]
Laboratories for:						
Life sciences	Yes	Yes	Yes	Yes	Yes	Yes.
Space science/applications	Very modest	Very modest	Very modest	Limited	Extensive	Extensive.
Materials science	Some	Some	Moderate	Moderate	....do	Do.
Technology development	Modest	Modest	Some	....do	....do	Do.
Observatories	No	Limited	Limited	Limited	....do	Full.
Data/Communication node	No	No	No	No	Yes	Yes.
Servicing of satellites	Modest	Modest	Modest	Modest	Extensive	Full.
Manufacturing facility (materials processing)	No	No	Limited	Limited	....do	Do.
Large structure assembly	No	No	No	....do	Moderate	Extensive.
Transportation node	No	No	No	No	....do	Do.[8]
Fuel and supply depot	No	No	No	No	No	Yes.
Response to reasons for space infrastructure:						
Maintain U.S. space leadership and technology capability	No	Little	Some	Modest	Considerable	Extensive.
Respond to U.S.S.R. space activities	No	Weak	Weak	....do	Strong	Very strong.
Enable long-term human presence in space	No	Little	Modest	Considerable	Extensive	Extensive.
Attention-getting heroic public spectacle	No	Weak	Weak	Modest	Modest	Modest.
Extended international cooperation	Little	Little	Potentially moderate	Potentially moderate	Potentially considerable	Potentially extensive.

TABLE 1.—COMPARISON OF SOME OPTIONS FOR EARTH ORBIT INDEPENDENTLY OPERATING INFRASTRUCTURE—Continued

System	Shuttle orbiter	Extended duration orbiter: Phase I	Extended duration orbiter: Phase II	Spacelab (developed as permanent infrastructure)	NASA infrastructure aspirations	
					Initial operational capability	Mature, fully developed
Promote U.S. commercialization of space	....do	Modest	Modest	Indeterminate	Indeterminate	Indeterminate.
Maintain vigorous NASA engineering capability	No	Negligible	Negligible	Little	Extensive	Extensive.
Enhance national security, broadly defined	No	....do	....do	....do	Indeterminate	Indeterminate.
Space travel for nontechnicians	Little	Little	Little	....do	Some	Some.

[1] Less if over full stay time.
[2] With Spacelab habitat.
[3] New technology required, limited laboratory space.
[4] Orbital maneuvering vehicle plus 2 free-flying unpressurized platforms.
[5] Reusable orbital transfer vehicle plus several more platforms.
[6] 60–90-day resupply.
[7] 90-day resupply.
[8] Includes launch to Moon, Mars, asteroid.

TABLE 2.—SPACE PLATFORMS THAT COULD BE SERVICED BY SHUTTLE OR ANOTHER SPACE INFRASTRUCTURE ELEMENT, THE ORBITAL MANEUVERING VEHICLE

Platform	Unpressurized Coorbiting Platforms[1]				Pressurized platform[2]—European modified spacelab
	Spas	Mesa	Leasecraft	Eureca	
Date Available: Now, or approximate assuming start in 1985	Now	Now	1986	1987	1989.
Cost: billions of fiscal year 1984 dollars	0.005	0.01	0.2	0.2	0.6.
Characteristics:					
Power to Users (kW)	0.6	0.1	6	2	6.
Pressurized Volume (ft^3)	None	None	None	None	3000.
Crew Size	....do	....do	....do	....do	3.
Miscellaneous	3,000 lb Payload	200 lb Payload	10,000 lb Payload	2,000 lb Payload	20,000 lb Payload.
Capabilities:					
Time on Orbit	10 days	8 months	Unlimited	6 months	Unlimited.
Laboratories for:					
Life sciences	No	No	No	No	Modest.
Space science/applications	Very limited	Very limited	Modest	Modest	Do.
Material science	....do	No	....do	....do	Do.
Technology development	No	....do	Little	Little	Do.

Observatories	do	do	Modest	Modest	Moderate.
Data/communication node	do	do	No	No	No.
Servicing of satellites	do	do	do	do	Do.
Manufacturing facility (materials processing)	do	do	Considerable	Modest	Considerable.
Large structure assembly	do	do	No	No	No.
Transportation Node (assembly, checkout and launch)	do	do	do	do	Do.
Fuel and supply depot	do	do	do	do	Do.
Response to reasons for space infrastructure:					
Maintain U.S. space leadership and technology capability	do	do	do	do	Do.
Respond to U.S.S.R. space activities	do	do	do	do	Modest.
Enable long-term human presence in space	do	do	do	do	No.
Attention-getting heroic public spectacle	do	do	do	do	Do.
Extended international cooperation	Yes	do	do	Yes	Yes.
Promote U.S. commercialization of space	Indeterminate	Yes	Yes	Indeterminate	Indeterminate.
Maintain vigorous NASA engineering capability	No	No	No	No	No.
Enhance national security, broadly defined	do	do	do	do	Do.
Space travel for nontechnicians	do	do	do	do	Do.

[1] Serviced with extravehicular activity.
[2] Serviced internally while docked.

Senator GORTON. Our next witness is Mr. Ian Pryke of the European Space Agency. We would be delighted if you would step forward.

We are very pleased you could be with us and look forward to your message.

STATEMENT OF IAN PRYKE, HEAD OF THE WASHINGTON OFFICE, EUROPEAN SPACE AGENCY

Mr. PRYKE. Thank you, Mr. Chairman.

My Director General has asked me to express his appreciation at being asked to testify before the subcommittee and his regrets at not being able to appear before you in person.

In line with your letter of invitation, my testimony will review ESA's work to date of relevance to the space station and present an overview of the agency's thinking with regards to international cooperation on the space station.

I wish to stress that the viewpoint presented here is primarily that of the ESA executive. We are currently working together with our member states in an effort to establish a concerted European policy on potential collaboration.

Next week NASA's Administrator, Mr. Beggs, will be visiting Europe and, and here I quote NASA, "explain President Reagan's space station initiative, assess international interest, and explore opportunities for cooperation." On this trip he will meet with senior government officials of four of ESA's major member states, and on his last day in Europe he will have discussions with the ESA executive and will address a meeting of all ESA member state delegations.

It is impossible to assess the outcome of the visit at this time, but it is reasonable to assume that it will prove as important to Europe's planning as to that of NASA.

In reviewing ESA's work to date of relevance to the space station, I must of course include the spacelab program. The major event in 1983 for ESA was without a doubt the STS-9/Spacelab 1 mission. This was the first flight of the complete spacelab system and represented the culmination of over a decade of cooperation between ESA and NASA on the program.

The mission was rated by both ESA and NASA as a tremendous success. All spacelab systems performed in accordance with specifications and requirements, and I think it is true to say that in both Europe and the United States the program was considered to be the largest and most successful example of international space cooperation in history.

Within our spacelab followon development program, we are currently undertaking the development of a European retrievable carrier. This platform, which would be carried into space by the space shuttle, will provide a capability to support experiments in space for periods well in excess of the maximum on-orbit shuttle stay time, and it is considered that a future generation of the Eureca space base could be a candidate component of an overall space station complex.

In summary, we feel it is reasonable to say that with the success of the Spacelab 1 mission and the ongoing efforts in other areas of

the program, Europe has adequately demonstrated its credibility as a developer and manufacturer of man-rated space hardware, and its ability to manage a large cooperative space venture, both within Europe and on a transatlantic basis. We have, therefore, established a sound background to be considered a viable partner in any space station collaboration.

ESA is currently engaged in an effort known as the long term preparatory program, studying possible options for Europe in the area of space transportation beyond systems currently under development. Our goal is the definition of an overall European long term policy in this area. One component of the program concerns orbital systems and includes an option involving participation in the U.S. civilian space station.

For the past 2 years, we have been actively involved in a number of activities relating to the space station and have enjoyed a successful collaboration, albeit on an informal basis, with NASA's space station task force. To date we have spent some $1.5 to $2 million on station-related activities. These have involved work on mission analysis to determine the use Europe would make of such a station, and an identification of the areas of technology where Europe could make a significant contribution to the development of the station.

To insure close liaison between ESA activities and those of NASA, the agency has located a "space station technical liaison engineer" in our Washington office, and we have also formed a space station team at ESTEC, our technical center in the Netherlands, to prepare for the next phase of the work.

Furthermore, in an effort to keep the results of our mission analysis up to date and relevant to European requirements, ESA has established a space station user panel which liaises with the different discipline-oriented user advisory groups of the agency.

As far as future budgets are concerned, the ESA executive has proposed to its member states that amounts of $5 million in 1984 and $20 million in 1985 be allocated to carrying out phase B studies. I should point out that our fiscal year is the same as the calendar year. We have also proposed an amount of $3 million in 1984 for supporting technology studies.

The formalization of any collaboration with NASA would, as we see it, take three forms, relating to different phases of the program. Prior to the start of phase B, a simple exchange of letters would serve to formalize our working arrangements. For the phase B itself, an ESA/NASA Memorandum of Understanding would be required. And for phases C, D, and E—the operational and utilization phase—the ESA/NASA MOU would need to be supplemented by an intergovernmental agreement between the United States and the European countries participating in the program.

In negotiating European participation in the program, ESA would be guided by a number of considerations:

Our share in the work would have to be such as to provide a stimulus to European technology;

We would want our participation to be visible, that is to say that we would be responsible for one or more key elements of the station, with clear interfaces, over which we would exercise full responsibility in the development phase;

Whatever the final choice of the hardware that we developed, we would want to have a clearly defined role in the operational phase of the space station. This would include ground operations and flight crew;

On the basis of its collaboration in the program, we would want to have access to the entire space station capability, not only to the element or elements we develop;

And finally, we would want the European commercial sector to have access to the station on terms that were comparable to its U.S. counterpart.

I would like to reiterate, Mr. Chairman, the point that everything I have said here relates to the point of view of the ESA executive. The delegations of our member states, at the meeting of the ESA Council on February 23 and 24 expressed their great interest at the opportunity presented by Mr. Beggs' visit to Europe of being informed in great detail concerning the space station initiative. Mr. Beggs will address a meeting of representatives of member states and associate members, to be held in the ESA headquarters on March 9. Following the visit, the ESA executive will enter into a new round of discussions with the member states in an effort to establish a concerted European viewpoint.

This concludes my testimony.

Senator GORTON. It has been reported that both Germany and Italy are working on their own space station proposal, called the Columbus, and they will soon present it to ESA for the agency's support. Would you comment on this proposal and on any other serious space station proposals being developed by members of ESA, and how that might affect your ability to work with the United States in its development of a space station?

Mr. PRYKE. Germany and Italy currently have studies running in their respective industries on the Columbus program. The intention is to complete these studies by the middle of the year and be able to make a proposal at that time to our member states for Europeanization of the program.

I do not really have any further details on their work at the moment. All I can say is, when they make a proposal for Europeanization the executive will have to carry out an analysis of that program and will have to make recommendations to its member states based on that analysis. So the Columbus initiative by Germany and Italy will play an important role in our deliberations on the space station.

To the best of my knowledge, there are no other initiatives really going ahead among our member states at the moment on a purely national basis.

Senator GORTON. Does this mean that until, say, the end of the year or that presentation, you are not really able to move forward in any cooperative arrangements with NASA on its proposal?

Mr. PRYKE. I think we would still be able to discuss with NASA the forms the cooperation will take from the policy viewpoint. In terms of the actual hardware we will be developing, the Columbus initiative will have a direct bearing on that.

Senator GORTON. It has been reported that ESA was not completely satisfied with its role in the shuttle/spacelab mission in November. Can you tell me whether or not this is true, and if so what

problems ESA did encounter in connection with this joint space endeavor?

Mr. PRYKE. I would say, Mr. Chairman, I have heard this matter expressed a number of times. I personally do not believe the statement the way it is formulated. I think with hindsight we can be unhappy with the content of the agreement we negotiated with NASA for the spacelab program. It has to be remembered, though that when we were negotiating—this was the early seventies—we were very much junior partners.

But having said that, I have to qualify that statement by saying that we cannot deny that NASA has fulfilled the negotiated agreement to the letter. I think we can have no complaints there.

Senator GORTON. You just may try to negotiate a better agreement next time?

Mr. PRYKE. I think we will have learned a lot from spacelab, and when we come to the next round of negotiations on the space station we will apply the lessons learned, certainly.

Senator GORTON. According to your testimony, one of the important criteria for European participation in a U.S. space station development is that ESA's share of the work would have to provide a stimulus to European technology. Can you give us any more detail on what type or level of stimulus would be needed to satisfy this criterion, and also tell us whether or not they have been presented to NASA and what its tentative response has been?

Mr. PRYKE. I think it is fair to say that we have discussed a number of technologies with NASA, but not in any detail, because we are only now entering a phase where we can formally discuss with NASA.

The reason that—stimulus to technology—is in the testimony is that we foresaw an option that could be considered as maybe a viable European contribution to the space station, which would be running a Detroit-type production line of spacelab pressurized modules. Now, that could be very interesting to the European industry concerned. However, it does not really give us what we want out of the program in terms of moving our technology out to the cutting edge in certain areas.

Senator GORTON. Are you optimistic in negotiating with NASA that you would come to an agreement which would meet those goals?

Mr. PRYKE. I am relatively optimistic. I would imagine the negotiations would be rather complex.

Senator GORTON. You stated that for 1985 ESA will request at least $20 million for space station activities. Can you give me any indication, as against the present $8 billion estimated cost of space station development, what the likely range of potential ESA contributions might be, assuming that you could meet these other requirements which you have laid out?

Mr. PRYKE. The agency has always considered that if we wanted to be treated as a viable partner on the space station we are going to have to come up with at least 10 percent of the budget. So based on NASA's $8 billion figure, I suppose the right ballpark would be about $1 billion, at least.

Senator GORTON. We have also had it reported that the President of France has urged the creation of a "European Space Communi-

ty" which would launch a space station to enhance Europe's defense systems. Would ESA want to or be expected to participate in such a military ESC space venture and would that have an impact on its participation in a civil space station effort by NASA?

Mr. PRYKE. If the European Space Agency was going to contribute to a military space venture, our member states would unanimously have to agree to rewrite our convention. As of the moment we are purely a civilian space agency. We are not allowed to have any involvement in military programs.

Senator GORTON. All right. Let us reverse the field on that question. At this point, of course, the U.S. Department of Defense has found no military requirements for the space station. But of course, it has been stated that DOD might like to use the civil space station for research and development.

If that were the case, would that have a serious impact on European participation and development and use of the space station?

Mr. PRYKE. I think it would certainly have implications, particularly as it involves the European Space Agency. I do not see that the problems would be insurmountable. I stress there, "the European Space Agency" because, if many European countries thought in terms of national or bilateral agreements with NASA, they are not governed by the same constraints that ESA is.

Senator GORTON. That leads me to some of the testimony that you have already heard of the two preceding witnesses on methods or options for international cooperation. One was a multinational or multilateral country consortium, perhaps patterned along your own, along ESA's charter. The second involves various forms of bilateral involvement.

Do you have any opinion as to which of those two approaches would likely be more effective or more successful?

Mr. PRYKE. If you are talking about the United States and Europe, then I would have to say the bilateral approach is from my point of view the obvious one, but the bilateral as between NASA and ESA, and not the United States to our member states. I think the majority of our member states, in fact, I think it is reasonable to say all of our member states, have indicated a preference for Europe's role in the space station, if any, to be coordinated by the agency.

[The statement follows:]

STATEMENT OF IAN PRYKE, HEAD OF THE WASHINGTON OFFICE, EUROPEAN SPACE AGENCY

My Director General, Mr. Quistgaard, has asked me to express his appreciation at being asked to testify before this subcommittee on "The issue of the civil space station and the implications and ramifications of international cooperation in its development". Furthermore he wishes me to convey to you his regrets at not being able to appear before you in person.

In line with your letter of invitation, this testimony: Reviews ESA's work to date, of relevance to the space station issue; presents an overview of ESA's thinking as regards international cooperation on the space station.

I wish to stress that the viewpoint presented here is primarily that of the ESA executive. We are currently working together with our member states in an effort to establish a concerted European policy vis-a-vis collaboration. When the ESA council met on February 23 and 24, the space station was an item on its agenda.

Next week the NASA Administrator, Mr. Beggs, will be visiting Europe (prior to going on to Canada and Japan) to, and here I quote NASA: "Explain President Rea-

gan's space station initiative; assess international interest; explore opportunities for cooperation".

On this trip he will meet with senior Government officials of four of ESA's major member states, the United Kingdom, West Germany, Italy and France. On his last day in Europe he will have discussions with the ESA executive and will address a meeting of all ESA member state delegations.

It is impossible to assess the outcome of the visit at this time, but it is reasonable to assume that it will prove as important to Europe's planning on cooperation, as to that of NASA.

With your permission I will submit the remainder of this testimony for the record and will summarize its key points for the subcommittee at this time.

Any review of ESA's work to date, of relevance to the space station, must of course include the spacelab program.

The major event in 1983 for ESA was, without a doubt, the STS-9/spacelab 1 mission. Although spacelab pallets had flown aboard the shuttle on two previous occasions, this was the first flight for the complete spacelab system, and represented the culmination of over a decade of cooperation between ESA and NASA on the program.

Spacelab was designed and built in Europe with European funds, under the direction of ESA. In fulfillment of the intergovernmental agreement between the U.S.A. and the European states involved in the program, and the MOU between ESA and NASA: One engineering model; one set of flight hardware; two sets of ground support equipment.

Have been delivered, free of charge to NASA.

An ESA/European contractor team has been in residence at KSC supporting integration of the spacelab 1 mission and will continue to provide engineering support through the spacelab 2 mission.

The SL-1 mission, launched on November 28, 1983, was rated by both ESA and NASA as a tremendous success. All spacelab systems performed in accordance with specifications and requirements throughout the flight. The only major system anomalies reported were the temporary breakdown of a high data rate recorder, later fixed by the crew, and the intermittent operation of a remote acquisition unit on the pallet.

All experiments within the payload were operated, the only major failures experienced in the European portion being: The failure of the microwave remote sensing experiment to operate in its active mode. The failure of the isothermal heating facility after 12 of a planned 22 samples had been processed.

The incomplete processing of 2 out of 6 samples in the mirror heating facility.

The data collected by some experiments was degraded as a result of the slip in the launch date to late November. However, NASA and ESA have been working together to identify reflight opportunities for these experiments, and to date all have been placed, with the exception of the metric camera.

Although difficult to define precisely the mission is deemed to have been about 95 percent successful.

I think it is true to say that in both Europe and the U.S.A. The spacelab program is considered to the largest and most successful example of international "space" cooperation in history.

Work continues in Europe on the spacelab follow-on production program in which additional spacelab flight hardware procured by NASA, under the terms of the NASA-ESA MOU, is being fabricated and delivered to the U.S.A. As currently planned, deliveries should be completed in 1985.

Within the so-called spacelab follow-on development program ESA is undertaking the development of a European retrievable carrier (Eureca). The Eureca platform will provide a capability to support experiments in space for periods well in excess of the maximum on-orbit shuttle stay time. In the case of the first Eureca mission, the schedule calls for it to be deployed from the shuttle on flight 81-A in October 1987, and retrieved and returned to Earth on flight 81-L in May 1988. The platform can carry a payload of about 1,100 kgs, and supply it with approximately 1.7 kW of power. It is considered that a future generation of Eureca (space based) could be a candidate component of an overall space station complex.

In summary, we feel it is reasonable to say that with the success of the spacelab 1 mission, and the on-going efforts in other areas of the program, Europe has adequately demonstrated its credibility as a developer and manufacturer of "man-rated" space hardware, and its ability to manage a large cooperative space venture both within Europe, and on a trans-Atlantic basis.

ESA is currently engaged in an effort known as the long-term preparatory program. This involves studying possible options for Europe in the area of space trans-

portation, beyond systems currently under development (i.e. Ariane IV, spacelab and Eureca). The goal is the definition of an overall European long-term policy in this area. One component within this program concerns orbital systems, and includes an option involving participation in the planned U.S. civilian space station.

For the past two years ESA has been actively involved in a number of activities relating to the space station, and has enjoyed a successful collaboration, albeit on an informal basis, with NASA's space station task force.

To date the agency has spent some $1.5-2.0M on station related studies. These have involved: Work on mission analysis to determine the use Europe would make of such a station (highest interest comes from the life science and materials science communities); an identification of areas of technology where Europe could make a significant contribution to the development of the station.

As far as the second of these items is concerned one area that is considered to show particular promise is spacelab derived hardware. We believe that the spacelab program has the potential of providing hardware, that could be customized to fulfill different space station functions (e.g. habitat, laboratory module, logistics module, etc.). As mentioned previously, there is also a feeling that the Eureca system has a good potential as regards platforms to be serviced by a space station.

To ensure a close liaison between ESA activities and those of NASA the agency has located a "space station technical liaison engineer" in our Washington office.

In an effort to keep the results of the mission analysis up to date, and of relevance to European requirements ESA has established a space station user panel which liaises with the different discipline oriented user advisory groups of the agency.

We have also formed a space station team at ESTEC, our technical center in the Netherlands, to prepare for the next phrase of work.

As far as budgets are concerned the ESA executive has proposed to its member states that amounts of $5 million in 1984 (ESA's fiscal year is the same as the calendar year) and $20 million in 1985 be allocated, for carrying out phase B studies. We have also proposed an amount of $3 million in 1984 for supporting technology studies.

As far as the formalization of our collaboration with NASA is concerned we would see this taking three forms, relating to different phases of the program. These would be as follows:

(A) Prior to the start of the phase B, a simple exchange of letters would serve to formalize our working arrangements.

(B) For the phase B itself an ESA/NASA memorandum would be required.

(C) For phases C, D and E (operational/utilization) the ESA/NASA MOU would need to be supplemented by an intergovernmental agreement between the United States and the European countries participating in the program.

In negotiating European participation in the program, ESA would be guided by the following considerations:

(1) ESA's share of the work would have to be such as to provide a stimulus to European technology.

(2) ESA would want its participation to be visible, that is to say that it would be responsible for one or more key elements, with clear interfaces, over which it would exercise full (development) responsibility.

(3) Whatever the final choice of hardware that it developes ESA would want to have a clearly defined role in the operational phase of the space station (both as regards ground operations and flight crew).

(4) On the basis of its collaboration in the program ESA would want to have access to the entire space station capability and not only to the element or elements it may develop.

(5) The European commercial sector would have access to the station, on terms that were comparable to those of its U.S. counterpart.

Finally I would like to reiterate that, as mentioned early in my testimony, what I have outlined here is the point of view of the ESA executive. The delegations of our member states at the meeting of the ESA council on February 23/24, expressed their great interest at the opportunity, presented by Mr. Beggs' visit to Europe, of being informed in greater detail concerning the space station initiative. Mr. Beggs will address a meeting of representatives of the member states and our associate members (Austria and Norway) to be held in ESA headquarters on March 9.

Following the visit, the ESA executive will enter into a new round of discussions with the member states in an effort to establish a concerted European viewpoint.

This concludes my testimony.

Senator GORTON. Mr. Pryke, thank you very much for being with us here today. You have helped us a great deal.

We will next hear from Mr. John Olson of the Washington State Citizens for Space and the International L–5 Society. Mr. Olson, you are most welcome here. As is the case with the other witnesses, your entire written statement will be included in the record, and we would like you to summarize it in not more than 7 minutes if you can.

STATEMENT OF JOHN J. OLSON, WASHINGTON STATE CITIZENS FOR SPACE AND THE INTERNATIONAL L–5 SOCIETY

Mr. OLSON. Thank you. Mr. Chairman, members of the committee, the Washington State Citizens for Space and the International L–5 Society are grateful for the opportunity to testify before you today.

I am John Olson, preliminary design engineer for the Boeing Co. First addressing matters of conflict of interest, I must make it clear I am not representing the company today. I am here on my own time, on private funds donated from the pockets of friends and our organization.

My personal motivation, as well as that of the two organizations I represent, comes from the deep conviction that this Nation should build and occupy a permanently manned space station. Members of the subcommittee have already heard much about the technical merits and specific missions that the proposed space station would accomplish. We would like to address the issue from a broader point of view.

While we feel the space station is an event of historic significance appropriate to the American heritage, we also feel it is an opportunity we cannot afford to ignore. Opportunity is a fleeting occurrence, as so clearly and poetically stated by William Shakespeare in his play Julius Caesar:

> There is a tide in the affairs of men,
> Which, taken at the flood, leads on to fortune;
> Omitted, all the voyages of their life
> Is bound in shallows and in miseries.
> On such a full sea are we now afloat;
> And we must take the current when it serves,
> Or lose our ventures.

The Apollo program was a venture of grand proportions. It was a statement to the world that America can still do what we are inspired to do. It gave us a strong sense of national pride. However, the direct benefits were few and, despite the tremendous indirect benefits, many people still ask why.

People were disturbed to know that most of the magnificent system wound up in the bottom of the sea. We needed something reusable. Therefore, the shuttle orbiter.

The space shuttle represents a capability similar to a pickup truck. Now, let us suppose you are a rancher needing to repair the fence line of the north 4,000. Imagine telling the foremen that they will have to do this: No. 1, do the job only from inside the cab or in the back of the truck; No. 2, not be able to throw the posts in the ground or unroll the wire; No. 3, get back within 2 hours. The space shuttle, to realize its full capability, needs a place to go

where it can unload its cargo and return for more, while a work crew gets on with the business of using the unique qualities of space.

What will a space station accomplish? We have already learned that, unconstrained by gravity, we can manufacture new products. We will have the capability of assembling very large spacecraft which would be cost prohibitive by any other means. And it is planned that the space station will be a commercially profitable venture, appropriate to our free enterprise system, and we can continue to meet the needs of science and space exploration.

If the historical precedents in technology have any validity, the greater value of what we can do will be found in discovering things which are now beyond our imagination or expectation. Nations once powerful and advanced stagnated or fell behind when they ignored a new techology or failed to recognize its potential. As a nation we could be at that point now.

Americans are given to patting themselves on the back as a nation of innovators. The phrase "Yankee ingenuity 'is well earned. Did we not invent the airplane, the robot, the transistor, liquid fuel rocketry? Did we not put the first man on the Moon?

True. We have also been guilty of dropping the technological ball. The Wrights invented the airplane, yet when World War 1 started France, England, and Germany had more than 2,000 aircraft, the United States had only about a dozen. The transistor, to Japan; robot, to Japan; liquid fuel rockets, to Germany; et cetera, et cetera.

Even now, the Europeans are becoming impatient with our slow progress toward a space station. The Japanese are getting into the space business, and the Russians have never slowed down.

We are descendants of people who boldly sought opportunity in a new land. America is no longer uncharted, hostile, or wild. That old frontier is gone, but the spirit of our ancestors lives on.

In my youth I was inspired by Charles Lindbergh and the "Spirit of St. Louis," and looked at the sky with dreams of flight and Earth travel. Our youth look to space and see exciting opportunities. Space is the new frontier.

Because of our staggering national deficit and other economic problems, there are some who say we cannot afford to develop the space frontier. This recalls attitudes of another time. The Grand Coulee Dam was built during the Depression of the 1930's, a period of extreme economic stress. Protesters railed: "We do not need it, we cannot afford it, too much power, it is a make-work project!"

Well, it was built and since then, with the basin irrigation project, it has changed a once semiarid desert into one of the most productive regions in the world. When the hydroelectric plant was first proposed, the opposition complained its power capacity would be more than needed. The demand now far exceeds its output, and the Grand Coulee is supplying only a portion of the power consumed.

To say we cannot afford the space station is like telling a destitute farmer he cannot afford to save his seed corn for the coming spring planting. We consider the station to be our seed corn of the future.

We tend to forget that most of the space station has already been paid for. The necessary technology and infrastructure has been largely developed by the Apollo, skylab, and shuttle orbiter programs. We do not have to design, build, and test a new launch vehicle. We do not have to build a new launch pad or a mammoth assembly building.

The space station itself is not as complex as Hollywood films would have you believe. It is a small technological step, but a giant leap in the evolution of Earth's progress in space.

On every shuttle flight the astronauts prove and extend the limits of what they can do. We have the people eager to go to space; so does the rest of the world. We have work to be done; so does the rest of the world. We have the technology to do it; so does Europe and Russia. Will this new frontier be developed by America? This decision, gentlemen, will be greatly influenced by your recommendation.

At the beginning of my talk I recited a quote from Shakespeare regarding opportunity. Paradoxically, the line preceding it reads: "We at the height are ready to decline." We cannot believe this Nation is ready to accept decline.

We urge your support for the space station to continue our tradition of moving with the future. The tide is at the flood and we must not lose this venture.

Thank you for this opportunity to appear before this committee. Any questions?

Senator GORTON. Thank you, Mr. Olson. In your testimony, both oral and written, you have alluded to some intangible benefits the Nation might receive from a space station development. What are some of these intangible benefits which might impact each of us as individual citizens and collectively as a nation?

Mr. OLSON. The intangible benefits are those which we cannot identify right off the bat. I think we are going to be naive to say, this is what the space station can do and that is what we are expected to do. Every time a new technology rises to the surface, it always works out that we discover there are a lot more things you can do with it.

For example, I remember the laser when it was first demonstrated that the laser would work. It burned a hole in a razor blade in a laboratory and somebody said: Big deal; we can do that with a punch press. And look at all the things that we can do with lasers now, and it is expanding every day.

I think it will be the same thing with the space program. It is, like I said, what we identify now that we are going to do, but the great value will be found in those intangibles, those things that we cannot identify; besides the other intangibles, national pride, things for children to shoot for.

I think if we are concerned about education in this country, kids would rather dream of things to shoot for than at. I think the idea that you might possibly become an astronaut and go to space is of great motivation, and motivation is the key to most educational processes.

Senator GORTON. Your testimony says that a space station, highlighted by a combination of a manned station and an unmanned research platform, will be the key element in a new pattern of

commerce. Would you explain how the space station infrastructure can be a key element in a new pattern of commerce?

Mr. OLSON. Well, the space station will enable us to do things that are very difficult to do now. For example, if we design a spacecraft to do a job up in space, so much of that cost of that spacecraft goes into designing deployment mechanisms. Most of it goes into building in redundancies so that the system is bound to work.

With the space station and the space platforms and men, we can avoid a lot of these difficult deployment mechanisms. A man can go out on EVA and simply uncrank the antenna, uncrank the solar array, and, if they do not work, fix them. We do not need to have a redundancy in all of our components. If we have a component that does not work, plug in a tester, find out what is wrong, fix it. It will actually reduce the costs of some of these things that scientists and other people want to do.

I think it will be an enabling process.

Senator GORTON. You have heard each of the three witnesses who preceded you speak about various elements of international cooperation in the development of the space station. I would like your comments on what role that ought to play, how major a part of the development of the space station the European Space Agency should take, for that matter Canada or Japan, and how you think this will affect our relationship with those nations.

Mr. OLSON. I am delighted to answer that question, but it falls outside of my expertise. As an engineer, I work at the drawing board most of the time, and how we would work with other countries and how we would deal with that I am a little hesitant to answer.

Senator GORTON. Do you think we should design and produce the entire space station ourselves, or should we ask our friends and allies to take the responsibility for particular components?

Mr. OLSON. No; I personally feel—this is my personal opinion. I feel that they should share in the process. Why not? They are going to be part of using it; they should also be part of designing it, part of building it, having suggestions. I think it could be a wonderful ventures for free nations to get together and harness space for the benefit of mankind.

Senator GORTON. Thank you very much, Mr. Olson. We are delighted to have had you here today.

Mr. OLSON. Thank you.

[The statement follows:]

STATEMENT OF JOHN J. OLSON, WASHINGTON STATE CITIZENS FOR SPACE AND THE INTERNATIONAL L-5 SOCIETY

There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune;
Omitted, all the voyages of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat;
And we must take the current when it serves,
Or lose our ventures.

—William Shakespeare, Julius Caesar

Space is not a mission, it is a place, an arena, like the ocean or the sky. We have a unique opportunity—the chance to sail a new ocean. If we don't rise to the chal-

lenge, others will. The type of space program we choose will say much about our culture, our values, and our outlook towards the future.

A space station is the next step in the evolution of our space program. Unlike Apollo, a space station will stay with us. Over time, initial capabilities can be incremented and new facilities can be developed. Research performed on the space station will lead to new materials, new products, and new visions. Your support of a space station today will be a sign of America's confidence in the future. It will be a beacon of hope to the peoples of the world, our children, and ourselves.

THE NEED FOR A FRONTIER

America is populated by descendents of people who, for one reason or another, left their homeland for life in a new land. The history of America is the history of successive frontiers. Each frontier provided new problems, new solutions, and a new field of operation. The frontier was a place where past solutions could be reviewed objectively, where new ideas could be tested, where attitudes were fresh and the people confident, where there was impatience with the restraints and scorn of an older, less flexible society.

The theme of America is one of constant movement, of progress, of achievement, and of restlessness. From the early explorers and settlers to the framers of the Constitution, from Daniel Boone and Benjamin Franklin to Neil Armstrong and Albert Einstein, from the transcontinental railroads and the Panama Canal to the landing of the Eagle on the Moon, the spirit of America is the search for a better way, a more representative and responsive government, a higher standard of living, greater knowledge, and more freedom.

For aspiring young minds of today, space is not a new and strange environment; it's something they've grown up with. As young people fifty years ago, inspired by Lindberg and the Spirit of St. Louis, once looked to the sky with dreams of flight and air travel, many young people today look to space. Today's youth expect space travel to become commonplace during their lifetimes. They see stories about space as stories about their frontier, where they will be able to learn and grow and build, free of the restraints and mistakes of the institutions and culture of the past.

WHY PEOPLE ARE NEEDED IN SPACE

Why put human beings on a space station? Human beings will bring intelligence, creativity, flexibility, reliability, and judgment. A human can react to the unexpected or unusual, and follow up on it. Had Alexander Fleming let a robot clean his petri dish, we would have missed the discovery of penicillin. When Skylab wrapped its solar panels around itself on its way to orbit, a very expensive spacecraft could have been lost, but astronauts repaired it. More recently Spacelab proved the need for humans to repair equipment and change experiments as results dictated different paths of study to pursue. A human being can quickly re-order priorities to take advantage of unusual conditions, as the Skylab solar observations so clearly illustrate.

If cancer researchers had to proceed in the same manner as traditional space scientists, they would have to design experiments ten years in advance and would not be able to reexamine a specimen, modify an experiment, or change conditions. How fast would cancer research progress?

Computers and robots are necessary to the success of space missions, but they will make a much greater contribution with men and women present to direct them, fix them, and at times ignore them. Indeed, we could pose this question: Would scientists want robots to do their work for them here on Earth? A terrestrial scientific laboratory, such as in a university or industrial research center, is typically crammed with the high-technology instrumentation needed to do reseanch. Many of these devices are automated, with computers directing the sampling of data. But is the human presence in such a laboratory superfluous? By no means! Such a laboratory is a beehive of activity by professors, technicians, and students—and these people are repairing or modifying their equipment more often than using it. Ask any graduate student, whose research depends on the proper function of complicated instruments, whether the devices by which he gathers data really require his personal attention. He will assure you as to the validity of "Murphy's Law"!

In fact, in a truly "cutting edge" laboratory environment, the judgment and direction of human beings are more important than ever. State-of-the-art instrumentation, like a newborn baby, demands constant attention.

LESSONS OF HISTORY

"Those who do not remember the past are condemned to repeat it."—George Santayana.

History has repeatedly shown that nations which abrogate their leadership pay dearly for such action. We can turn our backs on space—but that choice is the same as choosing to become a second-rate power.

As an example, professor Ben Finney, an anthropologist at the University of Hawaii, has studied the expansion of societies and nations across the ocean as an analog of space exploration. During the fifteenth century China was a major seafaring nation. However, the Chinese bureaucracy grew fearfull of the changes brought about by seagoing commerce and exploration, and had their fleets destroyed. By 1500 they had made it a capital offense to build a seagoing junk of more than two masts. In the words of Professor Finney, "Had the Chinese kept going, had they rounded the Cape of Good Hope, sailed north, then anchored off Lisbon, explored the Thames or cruised the Mediterranean, all of which they were technically capable of doing, how differently the modern world might have turned out."

If we commit to a space station and to succeeding steps, perhaps our civilization will not choose the path of stagnation taken by medieval China.

RECENT AMERICAN SHORTSIGHTEDNESS

"Grand Coulee Dam is typical of those things that won't have any more usefulness than the Pyramids of Egypt."—Dr. Henry Riggs, President, American Society of Civil Engineers, in Business Week, early 1933.

We need not look at the histories of other nations for examples of failure to grasp opportunities. Our own history provides many similar examples.

Americans pride themselves, rightfully, on their innovativeness. The idea that the past is not a strait jacket but merely a point of departure runs deep in our national psyche. Side by side with innovation however, we Americans have an unfortunate tradition of developing prototype technology, and then abandoning it out of misplaced conservatism. We drop the ball—allowing someone else to pick it up and run with it.

The Wright brothers invented the airplane—but due to apathy or disparagement in the United States, most of the early development work on the airplane was done in Europe. When World War I started France, England and Germany had collectively about 2000 aircraft compared to America's dozen.

The transistor was developed at Bell Labs in the late 1940's, but today we associate the transistor radio with Japan's phenomenal success in consumer electronics.

More recently, after US firms pioneered the techniques of large-scale integration which led to the development of the now ubiquitous microchips, Japanese firms perfected these techniques, and today are a major force in the semiconductor industry.

The early years of the "space age" itself provide another example of our squandering a technological lead. The US was widely perceived to be the world leader in rocket technology, but we dallied about until the Soviet Union overtook us and launched the first satellites and men into space. Indeed, in many ways they are still ahead of us.

In the past the United States was able to regain the lead because we were the world's economic leader, exuberant and resource rich. Today our leadership is no longer so pronounced, and we cannot rely on regaining a lead if it is lost. We can't play catch-up ball any more; the other players have learned the game, and they're as good as we are.

PLAYING FROM STRENGTH—OUR TECHNICAL EDGE

The space program is the only major enterprise that the United States government has undertaken in the last 35 years in which it has achieved unqualified success. As a people, we need to continue to believe that progress is possible. We need an occasional victory!

Space offers us a challenge, an opportunity, the ideal arena for victory. Our strength is the knowledge and skill of our people. America's scientists and engineers have put us at the leading edge of technology. Today we are best equipped for the technical challenges of pushing back the frontiers in space. Other nations are beginning to develop space technologies and capabilities, but we have an opportunity to visibly take the lead. We can set an example of a strong proud nation with vision, expanding humanity's horizons for the benefit of all. With such leadership we will buoy the spirits of our people, give hope to the world's poor and under-developed, and confound our detractors.

DESIRABLE SPACE STATION ATTRIBUTES

The space shuttle represents a capability, it's like a pick-up truck. In the American West, our recent last frontier, the horse has been supplanted by the pickup truck. The pickup truck, for all its utility would be severely handicapped in its function if the rancher had to perform all of his duties from inside the cab or in close proximity to his vehicle, and within a limited time frame. The shuttle, to realize its full capability, needs a place to go to unload its cargo and return for more while a work crew gets on with the business of utilizing the unique qualities of space.

What is needed? We must begin now to plan the next step in the development of space. The space station, highlighted by a combination of a manned station and unmanned research platform in low Earth orbit, will be the key element in the new pattern of commerce. It must be flexible enough to meet changing needs during the early years as we learn to take advantage of this new environment. We must make it amenable to free enterprise—not only physically, but administratively. Business must be able to move quickly and cheaply in space.

The development of new areas of science on the space station need not—and should not—diminish the support of traditional space sciences. The space station can provide valuable support, such as assembly of large probes for flights to the outer planets, post-launch test and repair of scientific satellites, and replenishment of consumables such as liquid helium for the highly successful IRAS satellite.

It is important that a vigorous exploration and research program in space be pursued. Such "pure research" generally has proved to have profound and unexpected practical benefit in the long run. One only need look, for example, at the tinkering with electricity and magnetism in the early 1800's that led to the electromagnetic theory, which in turn is the foundation of all today's electrical and electronic devices, from light bulbs to radios to computers.

We encourage international cooperation in the space station venture. An international effort implies that we consider the needs of our allies. If they know that we are dependable and available, they will plan with us and we can work together. Their actions and ours will be complementary. If we do not adequately consider their needs, our allies will be forced to compete with us; and someone will get hurt.

NEAR-TERM BENEFITS OF A SPACE STATION

What will result if we proceed with the space station? The space station is the first major step in the industrialization of space, a step which must be taken by any nation which expects to lead the march into the 21st century. Germany, Japan, and certainly the Soviet Union are keenly aware of the immediate economic impact of space manufacturing. The Soviets are proceeding, and the Europeans and the Japanese have space programs of their own. If our space station fails to meet the world's needs, the other nations will go a separate way. By building the right station, we have the opportunity to take a lead position in shaping a powerful new economic field. If we fail, we will be off to a slow start in what will become a terribly competitive and important arena.

Why is space so important now? Partly because our technology has begun to demand products that cannot be produced economically on Earth. Space holds two unique qualities for industry: zero gravity and vacuum. The first is impossible to achieve on Earth; the second is difficult and very expensive. Even with the high cost of getting to orbit, some processes promise economic gain if done in space. Among these are the growth of defect-free crystals for the next generation of very high speed integrated circuits, and the purification of valuable pharmaceuticals. Another advantage of a space station is its ability to act as a base camp and staging area for geosynchronous platform deployment.

The advantages of space for new industries are beginning to influence the type of scientific research planned for space. The biggest scientific role for the space station will probably not be the traditional "space sciences" such as solar observation or planetary science, but the new (for space) fields of materials science, biotechnology, electronics, and chemical engineering. These fields will have more immediate applications than the traditional space sciences, so their growth will be more rapid, bringing positive changes into our lives in just a few years.

We can clearly see many advantages to building a space station. However, the history of technology suggests that what we do not foresee will provide the most important benefits. (Few would have predicted the impact of personal computers even as recently as 1974.) The nations that seize new technology will lead the world into the 21st century.

FREE ENTERPRISE AND GOVERNMENT PARTICIPATION

We are staunchly pro-free enterprise; indeed, our enthusiasm for the potential of space stems in part from the vast expansion of opportunities it promises for individual initiative. We do not find free enterprise incompatible with government sponsorship of the first space station. We note that the government historically has had a role in frontier, capital-intensive enterprises, dating back to such undertakings as the Erie Canal and the transcontinental railroads.

In the Pacific Northwest, the building of the Grand Coulee Dam is a classic example of the government's pioneering role. Construction of this dam was, it should be noted, begun during the great depression, also a time of great economic stress. It is also instructive to recall that the Grand Coulee Dam was citicized bitterly as a pie-in-the-sky, make-work project. Even if it could be built, these myopic critics claimed, there would never be any market for the power.

The critics were wrong, and they were proved wrong within a few years of the dam's completion. The Grand Coulee Dam has provided a solid base for sustained economic growth in Washington State and the entire Northwest. Its electrical power and its irrigation water have provided thousands of outlets for private initiative, ranging from farms to aluminum refineries. It also brought a better life through the availability of dependable irrigation water and rural electrification.

The final irony is this: Far from there being "No market for the power", the Grand Coulee Dam is now largely used for peaking power because it cannot meet the large demand for baseload power.

Similar comments can be made about Hoover Dam and the Tennessee Valley Authority, other ambitious federal projects undertaken during the same time of economic hardship, that have paid off handsomely.

The space station is analogous to these endeavors. We are building an infrastructure in space, This infrastructure will underpin a new space industry to meet humanity's needs, and will provide a foundation on which to build for the challenges ahead.

INVESTMENT IN THE FUTURE

In communications, weather prediction, and intelligence gathering space capabilities are an integral part of our everyday lives. In areas such as navigation, search and rescue, astronomy, geology, and resource utilization progress is intimately dependent on advances in space. In many other areas space promises to have a profound and positive impact on our lives.

There is much promise for future advances in materials research, in life sciences, in astronomy, in Earth applications, and other sciences in space. We need to ensure that space sciences and exploration are not forgotten in the glamor of manned space operations.

An investment in a space station is analogous to a farmer's seed corn. A farmer knows that he must lay aside a portion of his harvest so that he can plant next year's crop. The farmer does not begrudge this investment in the future, but lays aside an ample supply—for he knows that some will spoil, some will be lost, and some will fail to germinate. A good farmer chooses his best seeds for seedstock because he knows that it will return a hundredfold, and the higher the quality of his seeds the better his prospects.

We should not begrudge our investment in science and space. On the contrary we should be eager to ensure a bountiful future harvest. And, as a farmer is especially careful of his seedstocks after a period of drought, so we need to be even more protective of our investment in the future when budgets are tight and the economy is stressed.

ON THE HORIZON

"I am impressed with the fact that President Roosevelt assembled the brightest scientists in America to the White House to help him envisage the things he might have to adjust in the future.

" 'I want you to tell me what to expect,' he begged, and after three days of intense speculation these men, whose job it was to anticipate the future and who commanded more keys to the future than any other group, failed to predict atomic power, radar, rockets, jet aircraft, computers, xerography and penicillin, all of which were to burst upon the world within the next years. They knew about the exploratory research, of course, but they could not believe it would produce functional products so soon. I assure you that if tonight you assembled an equal group of our most

learned men, they would not anticipate the simple wonders which will engulf us by the year 2000."—James Michener, Space.

The concept of progress, that each generation can experience a gradual betterment of its condition, is a relatively recent innovation. From the Golden Age of Greece until the Renaissance the progress ethic did not exist. If anyone sought knowledge, it was to be found in the writings of the ancients. Progress means a higher standard of living and increased diversity of choice for the individual, but it also means change, which can be difficult for those experiencing it. Having tasted progress, we cannot banish it from our minds.

We cannot predict the greatest benefits of commercializing space, any more than Columbus could predict what the discovery of America would eventually mean when he set out for the Indies. In moving into space, we will gain a new perspective which will lead us to new insights. The telephone was an interesting curiosity when first introduced; no one could foresee the revolution it wrought in our way of life. The automobile and the airplane have had equally revolutionary effects, yet both were disparaged at first.

By building industries in space, we help not only ourselves but also those who compete with us for the scarce resources of Earth. The nations of the Third World cannot yet go into space; we can. By moving on to new resources, we can relieve the environment of part of its burden of pollution. We also free ourselves from dependence on unstable monopolies of critical resources. Perhaps in space we will even find a way to lasting peace as nations no longer have to compete for scarce resources.

We have discussed some of the implications of the space station itself; beyond these are the implications of the space station for further exploration. Using the space station as a staging area, we can afford to return to the Moon in a more lasting manner than the Apollo missions. We can assemble large structures such as radio telescopes in space, or store fuel for deep-space missions. The second space station will be cheaper to build, and will likely be built by private industry.

CONCLUSION

"Of what use is a newborn baby?"—Michael Faraday, in reply to a question on the usefulness of electricity.

By the middle of the 21st century, the world's most powerful nations will all have strong state-sponsored or private space programs supporting them economically and technologically. Just as the nations that plied the seas were the great powers of history, so shall those who use space be the great powers of the future.

The space station is a crucial step toward that future. The world needs a gateway to space. The United States, a nation born and raised on the frontier is both materially and spiritually best equipped to provide that gateway.

The space station provides an avenue for new areas of research while providing support for the traditional space sciences.

The immediate return on the space station is tremendous. Better health, more jobs, and a higher standard of living are the rewards for your constituents. Technical leadership, economic health, national pride, and a feeling for the frontier are some of the rewards for the nation. The long-term benefits of space industrialization promise to be even greater.

Your choice on the future of the United States in space will be a step on the road to the future of the United States in the world. The exact space station features that you support or oppose, though not insignificant, will be smoothed by the winds of progress; but to turn away from space is a buy a plot in the graveyard of nations.

We urge you to choose the path of progress by supporting and adequately funding the space station proposal.

Senator GORTON. Our final witness for this hearing will be Dr. David Akin of the Massachusetts Institute of Technology. Dr. Akin, we are delighted to see that you have a visual for us today. You may proceed.

STATEMENT OF DR. DAVID L. AKIN, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. AKIN. I am very happy to be able to come here and talk to you about some of the technologies that will be available for use in the space station, particularly the applications of modern technologies such as teleoperation, robotics, and artificial intelligence.

There is a wide spectrum of operations, ways that you can do operations in space, from a completely manual one—an astronaut with a screwdriver, outside of the spaceship or inside—all the way to a totally intelligent system that understands and knows everything it can do and can do contingency operations.

There is a continual spectrum in between of mixes of people and machines to do operations in space. There is a tendency among people to say: We want to do everything with people, we want to do everything with machines. The major point I would like to make today is that for each particular task that you have to do in space there is an optimum mix of people and machines to perform the task, and the job that those of us in research have that is facing us today is to identify what those optimum mixes are.

Two particular technologies that I would like to talk about that have great implications to the space station are teleoperation and artificial intelligence techniques, expert systems. A good example of teleoperations is in this viewgraph, where you see a task, which is a satellite which we presume is broken, a panel on it that says "Open here to fix."

There are various approaches you can take to that. On the left you see what you might call dumb automation: a dedicated panel servicer that only fits that one panel and is built specifically for the task. This to some degree has been represented as the kind of approach that somewhat conservative spacecraft designers might take in the past.

In the center you see technology that was demonstrated theoretically in the last shuttle mission and it will be demonstrated practically in the next: A crewman in a pressure suit with tools, with auxiliary aids such as a man-maneuvering unit, going out and grabbing the satellite, fixing the satellite, and then deploying it back in space.

On the right you see the alternative of a totally automated system. You notice it is reading its own satellite repair manual as it is about to perform the task.

The particular task of a teleoperator is not to replace a person, but to remove the person away from the worksite. In a lot of cases, while this is very functional, there are some instances where it is very difficult or desirable not to send someone out in a pressure suit.

A good example of that would be a broken satellite in geostationary orbit where the radiation environment is such that you have very little time to safely spend in a pressure suit outside. Another example would be a contingency repair, such as hydrazene. Hydrazene is very reactive to most of the chemicals in a life support system. You do not even want to bring trace elements of hydrazene back inside. You would like to have the dexterity and the judgment capabilities of a human, but not expose a human directly to the risk.

This is a picture of a teleoperator that was designed and built and tested at Marshall Space Flight Center. I am sure it is an indication of what a teleoperator is like. You basically have to provide the functions of a human, so that you have on the top of it a camera system with pan and tilt that replaces the human eyes and the functions of the neck in panning and looking around.

You have arms. Arms have various functions. In a human we have very dexterious arms that can do anything. A teleoperator is difficult to implement that way, so on this particular one you see one arm which is specialized for grabbing and holding and one arm which is specialized for manipulating objects in a fairly dexterous manner.

You need a way to get around for both a teleoperator and a human, that is, some sort of a mobility unit in space that has gas jets. Underwater we have propellers.

The idea behind a teleoperator is that a person can sit on a space station, in a Space Shuttle, even on the ground, although that has some drawbacks, and manipulate as if he was at the work site and perform the task he has to do. That way if it takes you 12 hours for the teleoperator to get to the station the person is not occupied during that time and can do other things.

Teleoperation is a very powerful feature for operating in proximity operations around a space station.

Let me go on and talk about artificial intelligence techniques, specifically applications of expert systems to a space station. One of the big problems with having people in space does not relate to the people in space but to the people who support them on the ground. For example, there is a very large crew in mission control in Houston that supports the Shuttle mission every moment that it is in space.

As the mission goes by, as things fail, as things take longer or shorter, there is a continual process of revising and upgrading crew schedules so that you can get the maximum return from the limited time you have people in space. This is a very involved process and it involves judgments.

With some of the new capabilities of artificial intelligence, we have the capability today to create computer programs which can, if you will, mimic some of the judgment capabilities of the human mind. These programs are noted for having a great deal of expertise in a very limited field. For example, you cannot make an expert system which will replace a general practitioner, but you can make and people have made expert systems that will replace things like an expert internist-diagnostician.

In the same way, we feel that you can implement an expert system on a space station such that, rather than that it has to be in continual communication with ground mission control, the crew can interface with a knowledge base system on board and evolve their own schedules. In this case it might be an extra crew member or a logistics clerk to keep track of what needs to be done, what has the highest priority, what experiment requires what station attitude or use of consumables, which crew members are experienced and trained in which experiments; and over the course of each mission date it could evolve a new set of assignments, it could interact with the crew.

One of the problems that we found from skylab in long-term, especially the 56-day mission of skylab, was the crew felt a little put upon because of all these requirements that are being sent out from mission control. With a system like this, we can increase the habitability of the station, which is a very important issue, by giving the crew more control over their own environment.

In fact, we could also have such systems that would do things as monitor failure detection and diagnosis on a station, so that if you had a caution and warning as soon as the crew woke up, for example, the system could give them an overall opinion of what its internal model predicts the failure is and where to look.

The final thing I would like to leave you with today is to again reiterate that the best way to operate in space is to take the best features of both people and mechanical devices, such as teleoperators, and computer-based devices, such as expert systems, and bring all of them together to make the space station the most effective research and operations base in space that it can be.

Thank you.

Senator GORTON. That was perfectly timed.

Before I begin my questions, I want the record to note that Senator Lautenberg had intended to attend this hearing but was unable to do so.

In your testimony, Dr. Akin, you mentioned how expert systems could perform a number of unique functions, from mission control to diagnosing alarms. To what extent is this technology already developed, and how much of it do you believe will be available by, say 1992?

Dr. AKIN. The basic technology exists right now. There are companies which make a very considerable profit producing commercial expert systems for such things as taking data from geologists and predicting where oil fields lie. There are systems that have 8 or 9 years' worth of background in experimental diagnosis in hospitals.

What has not been done to date is the application of these systems to the particular environment of the space program. This is something that, given the desire to implement them and given the incorporation of the necessary computational power on a space station, can be very easily available on an operational capability of the station in 1991 or 1992.

Senator GORTON. In your testimony you mentioned that a breakthrough in current technology is needed to develop a fully autonomous system. Do I take it from your previous answer that you expect that breakthrough to occur in the immediately foreseeable future and is such a system desirable, or does that go against your testimony about the necessary mix?

Dr. AKIN. You have to keep the difference in mind between an expert system, which is an information device, and a fully autonomous servicer or teleoperator. A fully autonomous servicing device of any sort is a much more complex problem and will not be available in 1992.

You will be able to do a teleoperator, because all of the judgment and vision systems will be done by humans. You may be able to go a step farther and do what is called supervisory control, where for example you manipulate two modules close together by a teleoperator and then you push a button that says "Put them together," and it knows enough about the system to put the two modules together.

A fully autonomous or nearly autonomous system involves things like advanced vision systems, seeing and pattern recognition, some judgment capability that is beyond the capability of an expert system today. As I said, you may see the ability to do some routine

operations autonomously, but when you get into operations, things you have not thought of or do not know exactly what the problem is in advance, you will have to have either present on the site or present via a communications link a human being to perform those functions for the next 10 or 15 years at least.

Senator GORTON. How do our space-related technologies in the field of artificial intelligence and teleoperations compare with those of our Japanese and European counterparts?

Dr. AKIN. Currently we are doing more on applications of teleoperation and expert systems, at least as far as I know, than other countries are. If you look at the base technologies required for teleoperation—manipulators, basic robotics—Japan is at least the equal to the United States, probably ahead of us. Europe also has a great deal of installed robotics base in industry, not particularly in the space industry, and could certainly give us a run for our money.

I would say that both the Japanese and the Europeans are probably our equal in expert systems, and the Japanese are trying to leapfrog us into the next generation of computers, which will basically not need the kind of programing an expert system does today. We are definitely not out in the lead in any of these fields.

Senator GORTON. In each of these fields, can you comment specifically on NASA's work and whether or not it is your view that it has advanced the state of these technologies aggressively enough?

Dr. AKIN. I do not think that NASA is in a position to advance the state of the art in any of these in particular. What NASA has to do is to take present day technology, which is adequate for many of the things that we would like to do at first in the space station, and convert that to space hardware.

There is nothing intrinsically different between a robot arm and the kind of arm you would like to find in a teleoperator, except that the arm you buy from Unibate is not going to be space rated. What NASA needs to do—and I think they are fully cognizant of this need—is that they have to take the technology that is coming out of the academic laboratories and the research laboratories of industry and convert it for the space uses for which they need it.

I think they are aware of this. I do not really think I can comment with any authority on exactly what their level of effort is or should be.

Senator GORTON. How much interface is there between what we are doing in relation to space-related automated systems with the uses here on Earth and, conversely, what we are doing here on Earth directed at earthbound activities with relation to the space-related technologies? And how does private industry, the private sector, fit into all of this? Are we working generally in a field in which all three will benefit, or are they rather highly compartmentalized?

Mr. AKIN. There is definitely some overlap. In manipulator technology, actuators, motors, and so forth, actuation mechanical devices are not really that dissimilar between an industrial robot and a space robot.

There are particular requirements for some manipulators in space that have no bearing on an earthbound manipulator. A good example of that is the Canadian remote manipulator arm. It does a

good job of what it is designed to do, which is to take payloads in and out of the payload bay and manipulate them in the proximity of the Shuttle. But the arm itself cannot even hold its own weight, much less move on the surface of the Earth.

On something like that, there is no direct tradeoff back to the Earth. However, there are control system requirements to get around the fact that you have long flexible manipulators, and the ability to control one of these manipulators in space can be brought back to the Earth to increase, for example, the accuracy of an industrial manipulator.

The current technique of building industrial manipulators is very big and heavy so they are very solid and you can get accuracy that way. You can build them lighter and cheaper and use an increased level of intelligence in the control system to give you the accuracy you need. So there are tradeoffs in both directions between space manipulation and ground-based manipulation.

In other fields, such as the control systems, specifically intelligent control systems, I think there is the potential for NASA to lead the way in applying an artificial intelligence technique to manipulators and to servicing type devices.

Senator GORTON. Doctor, thank you very much for both your oral testimony and your illustrations of that testimony. I appreciate your coming to be with us here today.

With that, this second of four hearings on this general subject is adjourned.

[Whereupon, at 10:50 a.m., the subcommittee was adjourned.]

NASA AUTHORIZATION FOR FISCAL YEAR 1985

THURSDAY, MARCH 8, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:17 o'clock a.m. in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. Welcome to this third hearing of the Subcommittee on Science, Technology, and Space on the fiscal year 1985 NASA authorization.

On the first 2 days of these hearings, the subcommittee has examined the fiscal year 1985 budget request for NASA and, in particular, the space transportation system and the proposal to develop a permanently manned space station.

Today we consider in more detail NASA's space science and applications programs. Capitalizing on the promise of space depends, in part, on the success of our space science and applications programs. Congress has been presented a proposal to develop a permanently manned space station. Yet, unless we make a commitment to our space science and applications programs, we may discover that many of the users of the space station will not be in a position to maximize the utility of this facility. In this era of competition for resources, we must find the most effective and equitable distribution of these resources among all of NASA's programs.

There is much to commend in NASA's fiscal year 1985 budget request. This year's new planetary start, the Mars geoscience/climatology orbiter, gives hopeful indication that a steady, ambitious planetary program is underway. Also, the progress being made on two other space science projects—the space telescope and the Galileo orbiter and probe—heighten our anticipation of the forthcoming revelations from these two missions.

However there are still issues, however, that must be addressed. NASA's support for its research and analysis programs is vitally important to the basic research performed in our universities and national laboratories. An absence of vigorous basic research could manifest itself in missions that are not probing and comprehensive. We should not jeopardize our scientific missions by inadequate support for fundamental theoretical and empirical research.

In the area of NASA's space applications programs, I commend the new start of the upper atmosphere research satellite. This sci-

entific research mission will assist us immeasurably in developing a fundamental understanding of the atmosphere and the evolutionary changes in it.

However, there are issues that we must consider with the space applications programs. If we are to develop a productive partnership between the private and public sectors for space exploitation, we must adequately support the programs that are important to the entry of the private sector into commercialization.

Another issue before us is NASA's role in communications research and development. The United States is facing real—not symbolic—competition from other countries in the communications satellite industry. Our once commanding position in this field has been aggressively and often successfully challenged by our European and Japanese competitors. In deciding how to deal with this growing competition, we are also considering how this Nation distinguishes the Government's responsibilities in space from those of the private sector.

In addressing these issues, our first panel will comment on NASA's advanced communications technology satellite program and the related dimension of international competition.

We welcome Dr. Elizabeth Young of the Public Service Satellite Consortium, Mr. Richard Gould of the Institute of Electrical and Electronics Engineers, and Mr. Emanuel Fthenakis.

If they will step forward.

In the case of each of you, your entire written statement will be included in the record as if read. We will limit your formal oral testimony to 10 minutes each, and it is perfectly appropriate to present it in a shorter time than that if you wish and you can.

With that, Dr. Young.

STATEMENTS OF DR. ELIZABETH L. YOUNG, PRESIDENT, PUBLIC SERVICE SATELLITE CONSORTIUM; RICHARD G. GOULD, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.; AND EMANUEL FTHENAKIS, FAIRCHILD INDUSTRIES

Dr. YOUNG. Thank you, Senator Gorton.

The Public Service Satellite Consortium appreciates the opportunity to testify today before the Subcommittee on Science, Technology, and Space. We've been involved in assisting our members and others in using communications satellites and related technology since 1975. Today we do have a special concern about the direction of NASA's work in the satellite communications arena. We view with alarm the apparent reduction in budget support for this work, and we are deeply concerned about the proposal to curtail the advanced communications technology satellite program or ACTS.

We are equally concerned about the apparent lack of budgetary support for NASA's basic communications research and analysis program. Cuts in the level of that program began in fiscal year 1982, and today the basic program is funded at merely $9 million. Work done under this program supports NASA's joint endeavor with Canada on the very important mobile satellite program, and also the development of advanced component technology, which all of industry supports.

We believe that this basic research program in the communications area must be augmented by at least another $7 to $9 million in the fiscal year 1985 budget to bring it to a level where significant work can be done to benefit industry and the user community.

The ACTS program was initiated in 1978 and is a direct outgrowth of an assessment of the need to advance the state of satellite communications technology in order to meet the expected demand for service in the 1990's. The program content resulted from an intensive interaction between Government and industry, and involved not only systems suppliers, but service suppliers.

The objective of the ACTS program, as the committee knows, is to develop the high-risk advanced communications technology which will apply to multiple radio frequency bands and will support a wide range of future communications systems for NASA and other Government agencies and industry.

ACTS concentrates on the technology which will enable significant growth in the capacity and effective utilization of the frequency spectrum as well as the limited geostationary orbital arc. Delays have already occurred in the ACTS program, and a major delay in establishing a maturity of the needed technology is imminent as a consequence of the recent NASA decision to apparently limit the program to ground testing only.

A launch of ACTS was scheduled for 1988, which would have allowed the results of the flight experimentation to impact operational system designs planned for flight by commercial industry in the 1990's. Delays or elimination of the ACTS effort will, of course, have a direct impact on the systems to be implemented in that decade.

Benefits to be derived from the ACTS program are already evident. The presence of NASA as a catalyst in the technology development process has resulted in significant advances in technology and perhaps, more importantly, a perception that the advanced communications capabilities embodied in ACTS are realizable in future commercial systems.

The specific services that will be enhanced with an ACTS type of satellite include packet switching, electronic mail, business telephone services, teleconferencing, and various types of video distribution, as well as wideband data transfer. The ACTS program itself will enable rural and sparsely populated areas to receive service and test the efficiency of the technology. No commercially proposed system will as yet assist rural areas.

From its inception, the ACTS program was conceived as a prototype for service to small and medium businesses and rural populations in this country, as well as to establish large businesses and associations. But we view it as especially important that all potential users have the opportunity to experiment on a full flight test.

The current fiscal year 1985 budget for ACTS has led to the proposal that there be no flight test program, but only some type of ground test program, for which as yet we have seen no specifics. Without knowing what the agency has in mind, our own informal estimates are that to do any reasonable ground testing will still cost in the neighborhood of $150 million over the life of the program. The total estimated runout of the originally planned ACTS

program, including the flight test, would have been $354 million, of which some moneys have already been allocated and spent.

The unique accomplishments for the ACTS flight program that could not be achieved by a ground test program are, first, test verification of aspects of the ACTS technology such as the capability of a very narrow spot beam antenna, either fixed or scanning, to maintain pointing accuracies and electromagnetic performance in a space environment. Testing would be done for rain fade compensation, the ability to maintain system synchronization and timing in the presence of actual satellite motion, and the capability in a multiple user environment to achieve adequate time division multiple access system efficiency.

The experiment program planned by the agency would include industry financed development of needed ground terminal components and systems and industry financed ground terminals for experimentation. Also, the development of flight-qualified hardware would be only made possible in a flight test.

There has been one recent development which has led to considerable discussion with respect to ACTS. In December of 1983, Hughes Communications Galaxy, Inc., filed with the FCC for authority to operate two Ka-band communications satellites for supplying U.S. domestic services starting in 1988. Much discussion has centered around the notion that the presence of the planned Hughes satellite negates the needs for the NASA ACTS program.

If the technology content were comparable and wide access to that technology were available, as with ACTS, then the obvious conclusion would be that the need for the ACTS flight program has been eliminated.

However, upon examination of the Hughes filing, it is evident that their proposed system is responsive to their perspective of what the marketplace will need in 1988, and not necessarily responsive to the technology needs of the 1990's.

We are now facing a situation reminiscent of the decision in 1973 which drastically reduced NASA's R&D activities in satellite communications technology, and removed all flight experimentation from the NASA space program. We experienced a stagnation in high-risk technology advancements, and thereby encouraged entry into this U.S.-dominated field by Europe and Japan.

While we debated the wisdom of the NASA decision, a decade has passed. While the NASA advanced communication R&D program slowed, Japanese and European efforts and funding accelerated. Exclusive of the Soviet Union, the world's first domsat prime contract outside the United States was recently awarded to Aerospatiale of France for the Arabsat system.

The Japanese already have launched a communications satellite for tests in Ku and Ka-bands. Although the first series of these satellites were bought from U.S. industries, several of the key components and subsystems were developed and provided by Japan, and it is planned that all subsequent models will be developed and produced in Japan. It is also noteworthy that the Japanese have become the leading supplier of Intelsat Earth stations and are likely to take the world market lead in the sale of TV sets designed specifically for direct broadcast satellite reception.

It appears that both Japan and Europe have decided to forego major competition and at C and Ku-band and to leapfrog technology by concentrating on the 30/20 band. Indeed, the French agency responsible for their programs has been quoted as saying one of their goals is to:

> Consolidate our position in the principal domains of applications, including telecommunications, television and Earth observation, to construct a solid space industry, and enlarge our penetration of the international market for launchers, satellites, and associated services and ground equipment.

While the growth of communications industries in other countries is certainly a healthy and welcome sign, the United States needs to be certain it maintains policies that aid U.S. industry. A laissez faire policy that simply relies on individual companies to develop their own proprietary systems may work against the best interests of U.S. industry as a whole. There has been some concern that the ACTS program itself might be giving a leg up to the team that will eventually develop the technology. However, that team has agreed to cost-share, as have the experimentors, to a very considerable degree. We estimate some $150 million.

Also, with other private companies allowed to experiment on the program, technology results will be shared and technology transfer can be made possible.

We see three issues emerging as we focus on NASA's ACTS program within a larger context of NASA's work in the communications satellite arena. First, ACTS is time-critical program. Its technology makes an end run around the technology of the 1970's, but the technology must be developed soon to benefit U.S. industry and users in the 1990's.

Second, ground testing of the proposed technology would be insufficient. Ground testing does indeed contribute to technology development; however, the results will not have the impact of a flight system experiment.

And, finally, an issue emerges about policy and it concerns NASA's legitimate role in space communications. We believe that role has been adequately defined by this committee and others, and we believe that a cooperative endeavor by NASA and industry, such as has been originally proposed for the ACTS program and in other areas of NASA's basic research, is appropriate. Any shift in this relationship could have dire consequences for our ability to compete in the communications technology market and to meet the growing needs of our own business and public service communities.

By reopening the debate on this issue, we have already delayed the schedule for ACTS by a minimum of 6 months. As a consequence, the funding required in fiscal year 1985 to continue the flight program initiative would probably be half the amount originally required.

Mr. Chairman, this subcommittee and its parent committee have been vigilant in watching over NASA's programs. We look to your wisdom again as you consider the place of NASA's communications work, and specifically the ACTS program, in the context of what must be done in 1985 and beyond.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF ELIZABETH L. YOUNG, PRESIDENT, PUBLIC SERVICE SATELLITE CONSORTIUM AND SERVICES BY SATELLITE, INC.

INTRODUCTION

The Public Service Satellite Consortium appreciates the opportunity to testify today before the Subcommittee on Science, Technology and Space. The PSSC has been involved in assisting its members and others in using communications satellites and related technologies since 1975. (A copy of our current membership list is included.)[1] In the 1970's we coordinated experiments on NASA's Applications Technology Satellite (AT-6) and on the U.S.-Canadian Communications Technology Satellite (CTS). In recent years, we have assisted in enabling our members and government agencies to use the available commercial satellite communications systems. Our goal is to build a user community that can take full advantage of state-of-the-art technologies for public service communications requirements. We also work to ensure that our members will have opportunities to experiment with new developments in satellite communications.

Today we have a special concern about the direction of NASA's work in the satellite communications area. We view with alarm the apparent reduction in budget support for this work, and we are deeply concerned about the proposal to curtail the Advanced Communications Technology Satellite program (ACTS).

The ACTS program was initiated in 1978 and is a direct outgrowth of an assessment of the need to advance the state of satellite communications technology in order to meet the expected demand for services in the 1990's. The program content resulted from an intensive interaction between government and industry and involved not only system suppliers but the service suppliers (satellite carriers) as well.

The critical technologies embodied in ACTS as well as the system functional capabilities underwent review and critique by all who were willing to participate in the process of planning the advanced R&D effort of NASA. As a result, the program received and still has strong support from a broad cross section of the industry.

The objective of the ACTS program is to develop the high-risk advanced communications technology which will apply to multiple radio frequency bands and will support a wide range of future communications systems for NASA, other government agencies and industry. ACTS concentrates on the technology which will enable significant growth in the capacity and effective utilization of the frequency spectrum as well as the limited geostationary orbital arc. The critical ACTS technologies are also currently being aggressively pursued through technology developments and flight testing by the Japanese and the Europeans to enable them to be competitive with U.S. as suppliers of future satellite systems. Therefore, ACTS is aimed at helping to maintain U.S. preeminence in satellite communciations.

The ACTS experimental satellite, which provides very limited U.S. coverage capacity and lifetime (2 years), was originally planned to be launched in 1988. The experimental flight has been deemed necessary in order to verify that the technical risk associated with the very advanced technologies is at a level suitable for commercial implementation in the mid 1990's. The Ka-band frequency was selected as the operating frequency for ACTS because it represented a new band currently unused commercially but essential to future industry growth and because this frequency band also allowed experimental system implementation at small sizes (component sizes inversely proportional to frequency).

The technologies so developed will be applicable at other frequencies. The ACTS on-board switching and processing technologies are directly applicable to satellites at any frequency.

Several recent studies have indicated that demand for communications satellite services will increase in the United States and the rest of the world during the next two decades. The application of advanced technology is the best way to conserve spectrum and ensure that the increasing demands for satellite services can be met.

The recent flurry of filings before the FCC for satellite orbital positions support the general concern that saturation of the available spectrum is imminent. Not only must we consider looking to new frequencies for relief but we must insist on using this resource in the most efficient manner possible. This has been the essence and thrust of the NASA ACTS program with the expectation that the technologies being developed will allow effective and efficient expansion of satellite services in the 1990's.

The FCC is currently faced with the problem for the first time of having many more applications for new satellite systems than can be accommodated in the re-

[1] Retained in committee files.

maining orbital arc at both C-band and Ku-Band frequencies. ACTS related technologies cannot help in the current dilemma; however we must allow for continued growth in the use of satellite services and must not delay or defer the needed technology advancements to preclude a recurrence of this type of problem in the future. Delays have already occurred in the ACTS program and a major delay in establishing the maturity of the needed technology is imminent as a consequence of the recent NASA decision. A launch of ACTS was scheduled for 1988 which would have allowed the results of the flight experimentation to impact operational system designs planned for flight in the early 1990's. Delays or elimination of the ACTS effort will of course have a direct impact on the systems to be implemented in the 1990's.

BACKGROUND OF ACTS PROGRAM

In 1973, NASA's satellite communications program was drastically phased down. Since then, the once dominant position of U.S. industry has been both eroded and even by-passed in some areas. Both Japan and Western Europe perceived the phase-down decision as an opportunity. Their funding for communications satellite technology rose sharply in approximate synchronism with the NASA reductions. But the major thrust of these foreign programs was not directed at head-on confrontation with the established U.S. industry positions in C- and Ku-band. Instead, both Japan and Western Europe recognized that the real opportunity lay in the new 30/20 GHz or Ka frequency band and associated advanced technologies. In that band U.S. industry and neither an established position nor visible plans to reach such a position. By being first in the development and early demonstration of that technology, Japan particularly, expects to establish a dominant market position in exactly the same manner that U.S. dominance was established at the C and Ku-bands.

Recognizing the growing strength of foreign competition and the eroding position of U.S. industry, several committees and independent technical organizations recommended during the mid-1970's that NASA resume communications R&D. That step was taken in 1978.

In 1978 and 1979 detailed assessments for the future demand for communications satellite capacity were conducted for NASA by the U.S. communications industry. Their studies predicted a growing demand for satellite communications services which would exceed the capacity available using current frequency bands and existing technology by about 1990. The solution to this predicted shortage (which is now evident in the Americas region) lies in the introduction of new technology to improve spectrum utilization in general, and in the opening of the next available frequency band at 30/20 GHz to commerical use in a spectrum efficient manner.

The critical issue is developing the appropriate technology that allows use of the new band and improvement in the use of existing bands (C-band and Ku-band) so that service demands are met and the U.S. industry remains dominant in both the current bands and in the new emerging band.

IMPACT AND BENEFITS OF ACTS

Benefits to be derived from the ACTS program are already evident. The presence of NASA as a catalyst in the technology development process has already resulted in significant advances in technology and, perhaps, more importantly a perception that the advanced communications capabilities embodied in ACTS are realizable in future commercial systems.

The value of ACTS is two fold. First, the flight experiment will allow the technology developers opportunity to establish the performance of the advanced technology in a real, prototype operational environment. Secondly, it will allow both service suppliers and users to experiment with the new technology so they can become familiar with and develop a confidence in its use and assess its performance and cost for their own particular application.

The specific services that will be enhanced with an ACTS-type of satellite include: packet switching, electronic mail, business telephone services, teleconferencing, interactive video, wideband data transfer, low and medium speed data services, and various types of video distribution. The ACTS program itself will enable rural and sparsely populated areas to receive service and test the efficiency of the technology. No commercially proposed system will, as yet, assist rural areas. From its inception, the ACTS program was conceived as a prototype for service to small and medium businesses and rural populations in this country as well as to established large businesses and associations. But it is especially important that all potential users have the opportunity to experiment on a full flight test.

The current fiscal year 1985 budget for ACTS has led to the proposal that there be no flight test program but only some type of ground test program, for which, as

yet, we have seen no specifics. Without knowing what the agency has in mind, our own informal estimates are that to do any reasonable ground testing would still cost in the neighborhood of $150 million. The total estimated runout of the originally planned ACTS program, including the flight test, would be $354 million.

The unique accomplishments for the ACTS flight program that could not be achieved by a ground test program are as follows:

(1) Test Verification of the following aspect of the ACTS technology:

The capability of a very narrow spot beam antenna (either fixed or scanning) to maintain pointing accuracies and electromagnetic performance in a space environment.

The ability of rain fade compensation techniques to provide adequate link availability.

The ability to maintain system synchronization and timing in the presence of actual satellite motion and ground terminal perturbations.

The capability in a multiple user environment to achieve adequate Time Division Multiple Access (TDMA) system efficiency and flexibility using a scanning beam and baseband processor system.

(2) An experiment program which provides for:

Industry financed development of needed ground terminal components and systems. Under the flight experiment program a consortium of ground terminal manufacturers was to be formed for this development to provide a source for experimenter ground terminals.

Industry financed ground terminals for experimentation. Under the flight program many experimenters were going to provide their own ground terminal equipment.

Experiments designed by the industry to evaluate commercial implementation risks and benefits.

(3) The development of flight qualified hardware.

Above all, the past history of successful technology transfer from NASA to industry and the user community indicates that a testing and experimentation program is optimal. Indeed, most commercial satellite systems, whether in this country or elsewhere, have been preceded by periods of testing and experimentation. Experimenters become customers of future commercial systems. Builders of earth stations and other system components are then also in a position to test prototypes, perfect designs, and prepare to enter the commercial market.

(As an addendum to this section, I have included two lists of prospective ACTS experimenters who have already expressed an interest in being a part of the program.)[2]

HUGHES FILING AND ACTS

There has been one recent development which has led to considerable discussion with respect to ACTS.

In December of 1983, Hughes Communications Galaxy, Inc. filed with the Federal Communications Commission for authority to operate two Ka-band communication satellites for supplying U.S. domestic services starting in 1988.

The Hughes satellite system will use all of the available KA frequency bandwidth (which is five times that available at C and Ku bands). Its capacity will be about a factor of four times that of the largest satellite in service today. Two satellites are planned to be placed in orbit two degrees apart (one a backup for the other) to provide services over a ten year period. To a large degree, the Hughes proposed system is an extrapolation of current Frequency Division Multilple Access (FDMA) technology to Ka-band frequencies. The system will utilize current state-of-the-art integrated circuit technology for switching circuits on-board the satellite.

Much discussion has centered around the notion that the presence of the planned Hughes satellite negates the need for the NASA ACTS program. If the technology content were comparable and wide access to that technology were available as with ACTS then the obvious conclusion would be that the need for the ACTS flight program has been eliminated. However upon examination of the Hughes filing, it is evident that their proposed system is responsive to their perspective of what the market place will need in 1988 and not necessarily reponsive to the technology needs of the 1990's (One chart and one narrative comparison are offered to the Subcommittee as part of this testimony.) The Hughes filing is an important event and does represent a bold move by Hughes Galaxy, Inc. It should not however be confused with the tenets of the ACTS program nor considered to be a substitute to

[2] Retained in committee files.

attain the ACTS goals established by NASA in concert with the industry. There are significant differences in the technology planned for each system as there should be. Hughes is responding to operational service needs while ACTS is aimed at advancing the state-of-technology to allow options to be exercised in the future which will not be available if the program ends.

In summary, the ACTS technologies are different from those technologies required by the Hughes system and they require significantly greater advancements beyond the current state-of-the-art. The ACTS technologies are designed to provide very large capacity systems which utilize the frequency spectrum and oribital arc in a very efficient and conservative manner, provide a wide variety of services, minimize spacecraft weight and power to increase cost effectiveness, have a large degree of circuit routing flexibility and provide coverage within the continental United States.

These technologies will enable to build the advanced communications satellite of the 1990's.

FOREIGN COMPETITION

By all estimates, the market for communications satellites and their related systems and services is expanding and will continue to expand. The question now is whether the U.S. can remain a dominant supplier of the requisite hardware.

We are now facing a situation reminiscent of the decision in 1973 whch drastically reduced NASA R&D activities in satellite communications technology and removed flight experimentation from the NASA space program. We experienced a stagnation in high risk technology advancements and thereby encouraged entry into this U.S. dominated field by Europe and Japan. While we debated the wisdom of the NASA decision, a decade has passed.

While the NASA advanced communications R&D program slowed, Japanese and European efforts and funding accelerated. Exclusive of the Soviet Union, the world's first domsat prime contract outside the U.S. was recently awarded to Aerospatiale of France for the ARABSAT system. The Japanese already have launched a communications satellite for tests in the Ku and Ka-bands. Although the first series of satellites in this program was bought from U.S. industry, several of the key components and subsystems were developed and provided by Japan. It is planned that all subsequent models will be developed and produced in Japan. It is also noteworthy that the Japanese have become the leading supplier of INTELSAT earth stations and are likely to take the world market lead in the sale of TV sets designed specifically for direct-broadcast satellite reception. It is clear that U.S. industry no longer dominates the satellite communications market. It appears that both Japan and Europe have decided to forego major competition at C and Ku-band and to leapfrog technology by concentrating on the 30/20 GHz band.

In some cases, enterprising governments have been quite straightforward about their intentions. In France, the Centre National d'Etudes Spatiales (CNES), which manages most of the space program, has stated as a goal:

To consolidate our position in the principal domains of application (telecommunications, television, earth observation), to construct a solid space industry and enlarge our penetration of the international maket for launchers, satellites, and associated services and ground equipment.

It is also noteworthy that in Japan, while their overall space budget is necessarily smaller than that of the U.S., they devote a significantly larger percentage of that budget to what we would call applications. (A chart is attached, detailing the NASDA budget.)

While the growth of communications industries in other countries is certainly a healthy and welcome sign, the U.S. needs to be certain it maintains policies that aid U.S. industry. A "laissez faire" policy that simply relies on individual companies to develop their own proprietary systems may work against the best interests of U.S. industry as a whole. Also, our country's successful past history in the development of communications satellite technology shows that cooperative ventures between government and the private sector can result in rapid commercialization of technology.

There has been some concern that the ACTS program itself might be giving a "leg up" to the team that will eventually develop the technology. However, that team has agreed to cost share (as have experimenters) to a very considerable degree—some $150 million. Also, with other private companies allowed to experiment on the program, technology results will be shared and technology transfer can be rapid.

CONCLUDING REMARKS

Three issues emerge as we focus on NASA's ACTS program within a larger context of NASA's work in the communications satellite arena. First, ACTS is a time critical program. Its technology makes an "end run" around the technology of the 70's, but the technology must be developed soon to benefit U.S. industry and users in the 1990's.

Secondly, ground testing of the proposed technology would be insufficient. Ground testing does indeed contribute to technology development; however, the results will not have the impact of a flight system experiment. The planners and operators of future systems must make a judgement with regard to the technical readiness of any new concept and in particular those new concepts which dramatically change the way the business is to be conducted. As history has shown, prviate companies are not afraid to take risks when the extent of the risk is known. Ground testing of flight components and systems falls short of establishing confidence in the readiness of the technology for operational system implementation. The need for flight testing cannot be proved. As in many decisions, we must rely on lessons learned from history, the judgment of those who are knowledgeable and competent in the field and our own common sense. We must also consider the possible consequences of not following through with the ACTS flight experiment. It is not at all clear that we can afford to be wrong in this fast moving highly technical field. We must decide now whether the cost of ACTS is justified by the expected benefits—without the help of hindsight. Have all those who during the past five years closely followed the ACTS program development and continually supported the need for a flight experiment program been in error—or is the press of budgets within NASA going to cause history to be repeated?

By reopening the debate on this issue, we have already delayed the schedule by a minimum of six months. As a consequence, the funding required in fiscal year 1985 to continue the flight program initiative would probably be half the amount orignally required. It is my understanding that the total program cost as established by NASA would not be materially affected by the slip except for inflation effects. In our current inflation environment the impact would be quite small (about $6 million over the total program). I think the difficult question that must be answered is "Can we afford not to continue the ACTS initiative?"

The final issue that emerges is one of policy, and it transcends both ACTS and current budget issues. It concerns NASA's legitimate role in space communications. From work done by our organization and from my own experience in the communications industry, I would conclude that there must always be a NASA presence in the area of technology development and risk-taking. We have a commendably diverse, competitive industrial complex in this country. That has many benefits, but it militates against long-range planning and high-cost experimentation. If we can continue to have a partnership of government and industry, specifically in this case NASA and the aerospace/carrier industry, the U.S. can serve its own needs and serve the world. Any shift in this relationship could have dire consequences for our ability to compete in the communications technology market and to meet the growing needs of our own business and public service communities.

Mr. Chairman, this Subcommittee and its parent Committee have been vigilant in watching over NASA's programs to ensure that they reap the maximum benefit for U.S. industry and the user community. We look to your wisdom again as you consider the place of NASA's communications work and specifically the ACTS program in the context of what must be done in 1985 and beyond.

Thank you, Mr. Chairman.

COMMUNICATIONS SATELLITE OPERATIONAL NEEDS IN 1990'S AND ROLES OF ACTS AND HAC Ka-BAND S/C

Important new operational capability needed in 1990's (at Ku or Ka band) [1]	Enabling technology (to be developed by acts) [1]	Technology applicability to Ku or Ka band	Function (or technology) done by HAC Ka-band system
Customer premise low-cost terminals connected anywhere in U.S.A.	Scanning S/C beams. S/C base band processor (demodulation and routing).	Yes.	Neither function nor technology. Leaves out 50 percent U.S.A. population. Doesn't adequately satisfy many services (e.g., nationwide telephony).

COMMUNICATIONS SATELLITE OPERATIONAL NEEDS IN 1990'S AND ROLES OF ACTS AND HAC Ka-BAND S/C—Continued

Important new operational capability needed in 1990's (at Ku or Ka band) [1]	Enabling technology (to be developed by acts) [1]	Technology applicability to Ku or Ka band	Function (or technology) done by HAC Ka-band system
Flexibility to adjust amount of traffic between any 2 points (rates from telephony to teleconferencing)—fixed or demand assignment (DAMA).	TDMA up as well as down (like most current DOMSATS are doing).	Yes.	No. Uses simpler, inflexible FDMA up. Quite inefficient if traffic between 2 points is not multiples of T-1 (e.g., if need 27 telephony channels, may need to use 2 T-1 or 48 channels). Inflexible for DAMA.
Trunking. Complete interconnect 20 or more narrow beams.	SS-TDMA switch with growth to large sizes.	Yes.	No SS-TDMA switch.
Flexibility to accommodate many thin-route ground stations (say 1,000 or more).	Above technologies do.	Yes.	Probably not. Complete interconnection among 16 beam S limit stations to 200 max (for proposed 3,000 T-1 carriers).
Reduce outage due to rain (Ka- or Ku-band).	Power control in S/C and ground. Adaptive S/C decoding in baseband processor.	Yes.	None of these technologies are developed by HAC S/C.
Large spatial frequency re-use to increase usable spectrum at Ka- or Ku-band.	Multiple beam, low-sidelobe antenna.	Yes.	Not done significantly.
Use of Ka-band.	Develop reliable Ka-band hardware.	No. (only Ka-band)	Yes.

[1] As designated by carrier working group (AT&T, GTE, ITT, RCA Americon, SBS, American Satellite, etc.)

COMPARISON OF ACTS VERSUS HUGHES—KA-BAND SATELLITE

In recent filings to the FCC (November and December 1983), two companies, American Satellite and Hughes Communications, have initiated a move toward commercial use of Ka-band frequencies as part of the planned communications satellite systems. Although both of the proposed systems are significant advancements in satellite communications, the Hughes system, a large Ka-band satellite to be launched in 1988, represents a substantial increase in satellite capability. Because of this, it is appropriate to review these planned advancements as they might relate to the technologies in ACTS.

The Hughes satellite is a very high capacity system when compared to today's conventional satellites. It is larger by a factor of 4 in capability than the largest satellite in service today and is an extrapolation of current FDMA technology to Ka-band frequencies. Spacecraft demodulation and remodulation techniques will be used to improve the link capability and enhance the use of small earth terminals.

Conversely, ACTS is an experimental communications satellite system targeted on developing the advanced, high-risk technologies needed to enable operational systems of the 1990's. The critical technologies to be developed involve very high gain scanning multi-beam antennas, on-board signal processing and switching at both baseband and intermediate frequencies, and time division multiple accessing of the satellite resources. These technologies will permit efficient utilization of the orbital arc/spectrum resource at all frequency bands and enable continued growth in satellite communications service.

To facilitate a comparison, Table I lists the technology implications of the proposed Hughes system technologies related to those in ACTS. Major differences in access techniques, coverage spectrum efficiency and system flexibility are indicated.

TABLE I

	ACTS	Hughes Satellite
Access	TDMA	FDMA/TDM.
Traffic accommodation	Dynamic	Fixed.
Coverage	CONUS	Limited.

TABLE I—Continued

	ACTS	Hughes Satellite
Effective frequency reuse	Greater than 6	Less than 3.
Orbit spacing	1°	2°.
Adaptive rain fade compensation	Yes	No.

Because of these technology implications, limiting advances in technology to the level of the proposed Hughes system will constrain the arc/spectrum efficiencies and growth potential of future satellite systems far below the capabilities permitted by ACTS technology.

A review of the spacecraft antenna characteristics (Table II) indicate a similar approach to antenna geometry exists, but the reconfigurable beamforming network and scanning beam system of ACTS is a major technology advance. The increased demand on antenna performance by the ACTS requirements is also indicated.

TABLE II

	ACTS	Hughes
Type	Dual	Dual offset Fed.
Beam forming network	Reconfigurable	Fixed.
Fixed	30 to 100	16.
Scanning beams	6 for Conus coverage	0.
Isolation:		
Spatial	Yes	Yes.
Polarization	Yes	No.
Time	Yes	No.

Only ACTS allows buffering on the spacecraft to facilitate processing of the uplink and downlink signals and allows switching and routing the data rates down to a single voice channel. High rate demodulation of ACTS permits use of significantly lower parts count on the spacecraft. The increased flexibility of the ACTS baseband processor will allow freedom of choice as to system response to changing traffic patterns in operational systems.

TABLE III

	ACTS	Hughes Satellite
Uplink and downlink buffering	Yes	No.
Demodulators:		
Type	Burst (TDMA)	Continuous (FDMA).
Rate (MBPS)	27.5 and 110	1.5
Numbers required	100's	1,000's.
Baseband processing	Yes	No.
Baseband circuit routing	Multiples of 64 KBPS	1.544 MBPS only.
Adaptive rain fade compensation	FEC and burst rate reduction	None.

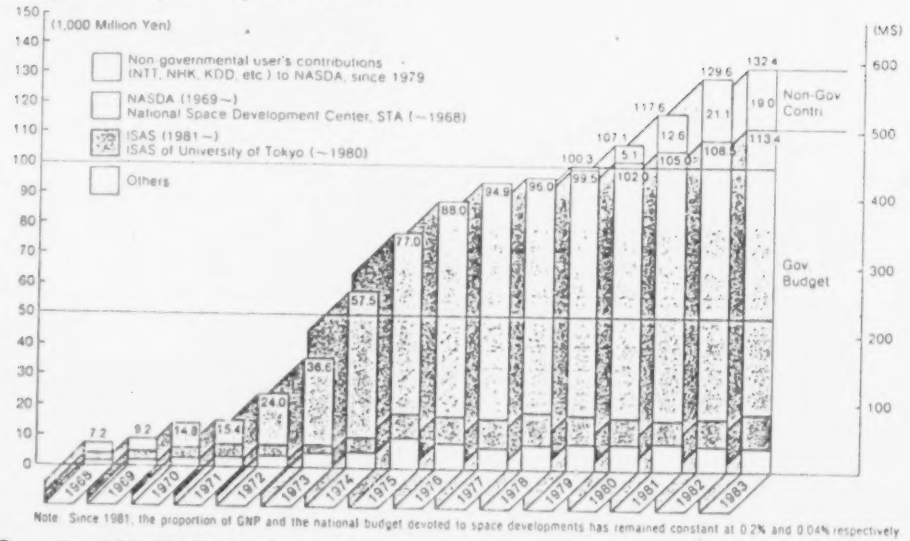
In Table IV, a limited comparison is made of the matrix switch technologies of both systems since only limited information was available in the filing. Fundamentally, the ACTS switch will allow a dynamic response to assigning channels in response to satellite traffic and is based on the very fast switching capability of GaAs FET's.

TABLE IV

	ACTS	Hughes Satellite
Reconfigurability	Dynamic	Static.
Matrix size	Comparable	Comparable.
Switch speed	20 nanoseconds	Unknown.
Switch technology	GaAs FET	Do.

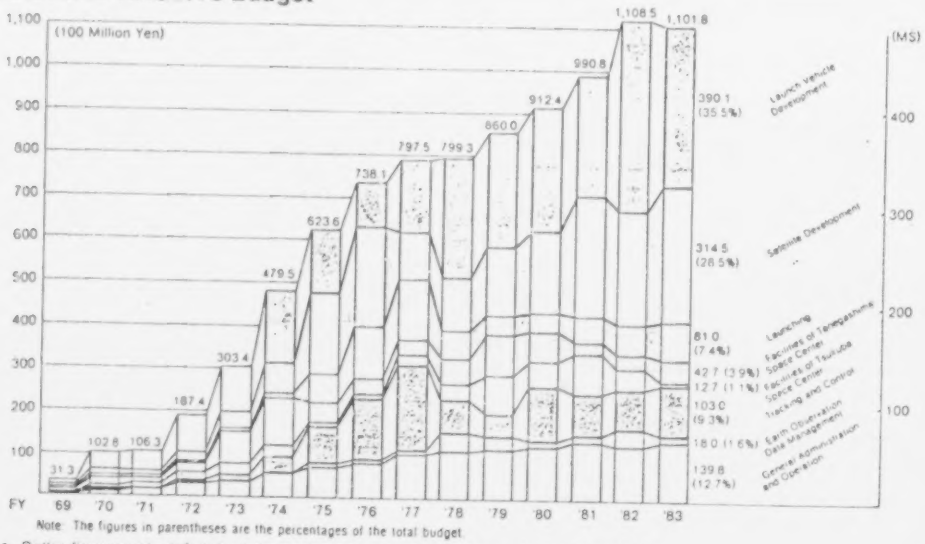
In summary, although the Hughes satellite is a significant advance in many ways over currently operating commercial satellites, it does not duplicate, in any significant way, the technologies in ACTS. The proposed Hughes satellite is very similar to the planned Italian satellite proposed for launch in 1986. Development of ACTS technologies including fixed and scanning beam antenna systems with baseband processor systems is still needed for the advanced satellites of the 1990's.

Budget for Japan's Space Activities



Note: Since 1981, the proportion of GNP and the national budget devoted to space developments has remained constant at 0.2% and 0.04% respectively.

Growth of NASDA's Budget



Note: The figures in parentheses are the percentages of the total budget.

• *Dollar figures calculated, for information only, at rate of 240 yen to the dollar (U.S.)*

Senator GORTON. Mr. Gould.

Mr. GOULD. Thank you, Senator Gorton, members of the committee, ladies, and gentlemen.

My name is Richard Gould. I am here today on behalf of the R&D committee of the Institute of Electrical and Electronic Engineers. We have a quarter of a million members worldwide, of which 200,000 live and work in the United States, making us the world's largest professional society.

It is an honor to be asked to discuss the ACTS program of NASA and its impact on our future ability to supply our own telecommunications needs and to supply space and ground equipment to other countries for the same purpose.

We are here today to support and urge restoration of funding for the NASA ACTS flight program in fiscal year 1985. In the audience is Dr. Russell Drew, vice president of the IEEE, who is available for questions on any other elements of IEEE's outlook on technology and the views of the institution in other areas of public policy.

As you know, NASA has been planning this ACTS flight program, since about 1977. This flight program would have culminated in the construction, launch, and experimental operation of an advanced technology spacecraft in the 20 and 30 GHz frequency bands, and it was intended to pave the way for the commercial communications satellite systems to serve our expected needs for space telecommunications as we enter the next century.

There was broad support for this program which was instituted some 7 years ago. The program began with studies of the requirements and has had participation by common carriers, by spacecraft manufacturers, researchers, experimentors, and universities. We are going to need the technology ACTS would have developed and tested, not only to satisfy the growing demand for domestic and international telecommunications, but to put us in a position to compete in world marketplaces for the sales of spacecraft and Earth station hardware. We will also need this technology to respond to the growing demands of other countries for orbital space and frequency allocations that we have witnessed in the last several years in international forums. There is concern that these precious resources will be gone when they have needs for their own communications satellite systems.

The answer to their demands should not the imposition of plans that assign slots in space before they are needed, in perpetuity, to countries to guarantee them access to the orbit. A much better way is to develop the technology to provide increased capacity which will satisfy the requirements of all users of the orbit.

"1984" was a work of fictions until—January of this year, that is. The year 2001 is still fiction, but in only 17 years it will be a reality. We can look back at the work "1984" and see that much of the technology that was described there is now actually a part of our daily lives: Video and audio tape recorders, closed circuit and broadcast television, cable TV, information networks, and data banks. And even some of the technology in the movie "2001" is here today: smart computers, planetary and space exploration, space vehicles, interplanetary communications to tie those devices and those places together.

Perhaps the actual needs that will arise by the year 2001 will be not all of the sometimes fanciful applications described in the movie, based on the story by Arthur Clarke, but we cannot even safely discount his visions. After all, it was Dr. Clarke who, in 1945, pointed out the unique characteristics of the geostationary satellite orbit for communications which is now heavily used.

But we do not even have to look at science fiction movies or books to ascertain the demand for telecommunications that will be placed on the geostationary orbit. The most recent evidence is a report by the FCC Advisory Committee for the impending 1985 Space Services Planning Conference—a conference, by the way, at which we will be confronted with the demands of other countries for orbital assignments. In preparation for that conference, the advisory committee analyzed the demand for satellite communications and compared it with the capacity that could be placed in orbit. Their conclusion was that demand for transponders would exceed the supply by the year 2000.

The prediction of available capacity was based on certain advances in technology, but those advances did not include any of the developments that would have been explored in the ACTS flight program. Thus, the ACTS program provides a way to close that gap: to provide the technology that we know will be needed.

That was only one of the studies that demonstrated the demand. NASA itself, early on, sponsored two independent studies by common carriers, organizations who should know what demand will be. Those studies by Western Union and by an ITT subsidiary, predicted that our supply of transponders in space could not equal the demand by about the turn of the next century, by the year 2001.

Even though this and other research has been available, it is difficult, even for experts in the field, to accept the rapid growth in communications requirements. For example, a spokesman for Hughes Aircraft Co. said before this very committee, in March 1982: "Who is planning to use this band? Unfortunately, there is no commercial customer who plans to use the 20/30 GHz band for broadband service." Within 2 years, Hughes found out that there was indeed a customer for such broadband services—itself. In December 1983, it filed an application with the FCC for a broadband system in the 20/30 GHz band.

One limitation of this Hughes filing however, is that it is not broad enough. It is neither broad enough in the effective bandwidth that it will have and therefore how much reuse it will make of this precious resource of frequency, nor is it broad enough in concept to supply the amount and kind of space communications that three independent studies have shown will be needed by the year 2001.

In comparison, the NASA ACTS flight program would have developed many elements of technology that will be able to increase the effective capacity of the orbit: multiple scanning, spot beam antennas that provide frequency resuse; digital time division multiplex; high-speed baseband processors that have onboard processing; and onboard switching of communications that permit the switching of individual circuits in the satellite—rather than groups of trunks—which will enable communications from a small Earth sta-

tion to go only to the Earth station for which that traffic is intended.

Where does all of this technology come from? In the 1800's the explorers of science and engineering could work in their homes and discover great truths. The "gentleman scientists" of England—Kelvin Rayleigh, Thompson, Rutherford—worked at home and gave us many of the scientific laws that we use today.

In the next generation, Steinmetz Tesla, Edison and Armstrong among others—including David Sarnoff, a founding member of the IEEE, by the way—worked in industrial laboratories. But today, even those facilities, and that kind of support are not adequate for the complexity of the developments that are going to be needed for the next generation of systems. These problems are too big for any one company. Note that one company that did supply a satellite system on its own in the 1960's—AT&T—has been broken up, so there is not even the AT&T giant with us now to sponsor satellite development by itself. For the most part, the Government has been the developer of satellite systems for the last 20 years, and we look to NASA to continue the fundamental and essential work that will give us the capability of providing these communications in future years.

The risks and the costs are too great for any one company to sponsor. But if NASA promotes and guides this advanced communications technology development, then NASA "ACTS" for us all!

Thank you.

[The statement follows:]

STATEMENT OF RICHARD G. GOULD, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Mr. Chairman and members of the Committee: My name is Richard Gould. I am appearing before you today on behalf of the R&D Committee of the Institute of Electrical and Electronics Engineers (IEEE). The IEEE is the world's largest technical professional society with about 250,000 members worldwide, of which 200,000 live and work in the United States. It is an honor and a pleasure to be asked to discuss the ACTS program of NASA and its impact on our future ability to supply our own telecommunications needs and to supply space and ground equipment to other countries for the same purposes.

NASA has been planning an Advanced Communications Technology Satellite (or ACTS) Program since 1977. This Program would have culminated in the construction, launch and experimental operation of a highly sophisticated, advanced technology spacecraft, operating in the 20 and 30 GHz frequency bands and having an expected life to two years. The Program is intended to pave the way for the commercial communication satellite systems to serve expected needs as we enter the next century.

After four years of studies designed to confirm technological feasibility and proof-of-concept, NASA conducted a lengthy competitive procurement and fact-finding, and selected the RCA team (RCA, TRW, COMSAT, Motorola) for the system development contract. However, in late 1983, as these contracts were about to be signed, both the American Satellite Company and the Hughes Aircraft Company filed applications with the FCC for commercial satellite services that would operate in the same frequency band as the NASA ACTS Satellite and when the fiscal year 1985 budget was presented, the funding for the NASA ACTS Satellite was virtually eliminated.

The drastic curtailment of the ACTS program raises several questions.

1. Will the U.S. really be better off without the ACTS program as originally designed?

2. Will MILSTAR or the Hughes commercial 20/30 GHz commercial Galaxy system help us meet communications requirements in a dozen years or so?

3. How much of those needs can it fill?

4. What are the international implications of falling behind in the field of communications satellites?

COMSATS IN PERSPECTIVE

"1984" was a work of fiction—until January of this year. The year 2001 is still fiction, but it too will be a reality in 17 years. Much of the technology explicit or implicit in the book, "1984", is a part of our daily lives: video and audio tape recorders, closed-circuit and broadcast television and both cable TV and information networks and data banks.

Even some of the technology predicted for the year 2001 is the movie of that name is also with us today: smart computers, space vehicles, and the interplanetary communications to tie such devices and places together. Our actual needs for this technology will not necessarily be for the sometimes fanciful applications and purposes depicted in the movie based on the story by Arthur C. Clarke. But even on that score, we shouldn't discount entirely Mr. Clarke's visions: after all, he was, in 1945, the first one to point out the unique characteristics and advantages of the geostationary satellite orbit for communications.

We don't have to look at science fiction books or movies to ascertain the demand that telecommunications will place on that geostationary satellite oribit. For example, a recent report of the FCC Advisory Committee on the impending 1985 ITU Space Services Planning Conference, has analyzed the demand for satellite-carried telecommunications, and compared it with the capacity of transponders that could be placed in orbit. Their conclusion is that demand will exceed supply between 1990 and the year 2000, for both U.S. domestic requirements and international, transatlantic ones. The date at which demand will exceed the maximum possible supply depends on the assumptions that are made of the advanced technology that will be employed. The most optimistic conclusion—that demand will not outstrip supply until shortly after the year 2000—assumed the development and incorporation of advanced technology in the areas of digital transmission and improved antennas, but did not include any of the sophisticated technology that would be developed in the ACTS Programs. In other words, if we do not develop and employ technology having a greater communication-carrying capacity than that now being contemplated for commercial satellite systems, there will be a shortfall.

It is not only this study that makes such predictions. One of the first steps taken by NASA in the development of the overall ACTS Program, was to determine communication satellite demand in future years. Two independent organizations—Western Union and U.S.T. & T., an ITT subsidiary, performed studies in 1979 for NASA. Both of these knowledgeable communication carriers agreed that demand would exceed transponder supply by the mid-1990's. In 1983 NASA had these two carriers reconsider the same question to make certain that the earlier forecasts were still reasonable. These recent appraisals increased the likely capacity of satellites, based on advances in technology in the past four years, and also increased the expected demand figures, based on recent actual growth in satellite usage. The overall result of the recalculation was to predict that saturation would actually occur only a few years later, near the end of the 1990's.

But nobody's predictions are perfect. For example, Hughes Communications Galaxy, Inc. reversed itself within a period of less than two years on whether there was a need for 20/30 GHz systems to serve the commercial market.

In testimony before this very Committee, a representative of Hughes Aircraft stated on March 30, 1982 in commenting on the NASA ACTS Program:

"Who is planning to use this frequency band? Unfortunately, there is no commercial customer who plans to use 20/30 GHz for broadband service."

Less than two years later, both Hughes and American Satellite Company found that there were indeed commercial customers for 20/30 GHz broadband services. The Hughes application of December, 1983 to the FCC is for a broadband 20/30 GHz system, of the very kind it suggested had no prospective customers. This change of view was presaged, it should be noted, in a Hughes statement before the 4th World Telecommunications Forum in Geneva, Switzerland (see attachment 1) in which the value of opening the 20 and 30 GHz band to commercial services was recognized.

The current filing by Hughes calls for a broadband system. However, it is not broad enough in terms of the effective bandwidth it will provide (and hence the use it will make of the radio frequency spectrum at a given orbital location), nor is it broad enough in scope to develop the technology that will be needed by the United States and others soon after the turn of the century.

In comparison with the ACTS Program, the technology that will be incorporated in the proposed Hughes 20/30 GHz Galaxy system is not, by far, the technology that

will be needed at the beginning of the 21st Century—only 17 years away. The elements of technology to be incorporated in both of these programs is given in Attachment II.

Galaxy will not equip us with the technology necessary to satisfy our increasing consumption of, and need for space borne channels of communications. At best, Galaxy will put off for a few years the shortages predicted by the WU and ITT studies, and by the FCC Advisory Committee of experts.

Support for the ACTS flight Program in the telecommunications, spacecraft, ground equipment and user communities has been very strong and widespread. The experts agreed on the technology that needed to be developed. They also recognized that such development—and the demonstration of that technology—was likely to be so costly, and so risky, that no company, or group of companies, would—or could—shoulder the burden of bringing it into being. Not only is it necessary to develop the individual components, subsystems and techniques, but they must be integrated into a working spacecraft to make sure that they work together in an operational environment. This means an extended, in-orbit, operational test of long enough duration to judge performance under the propagation conditions to be experienced by follow-on, commercial systems. Even if it weren't for the propagation vagaries in this new, untried frequency regime, inflight experience would be essential. The ACTS Program involves a multiplicity of new techniques, components and technologies, all pushing back the frontier—all extending the state of the art.

APPROPRIATENESS OF THE GOVERNMENT ROLE

In other countries, the telecommunications and space organizations are part of the government. Those governments sometimes take enormous risks, develop the technology, and turn it over to their own telecommunications operating entities—the state-owned carriers, or the government broadcasting service. It is unnecessary for the IEEE to explain to the Congress of the United States the structure of our own telecommunications enterprise, but permit us to review certain aspects of that structure to make an important point. The development of the most advanced space technology has largely been a function of government (using agencies such as NASA). It was NASA that made possible the commercial telecommunications satellite industry through their in-house research and development, and through its funding of such notable programs as the Hughes Syncom series (the first geostationary satellites) and Fairchild's ATS–6, which brought educational television to Indian villages and explored a multiplicity of services in new bands while stationed over the United States. Most recently, in 1976, NASA in cooperation with the Canadian Department of Communication, also demonstrated high-power broadcasting-satellites in the 12 GHz band with the CTS/Hermes spacecraft and program.

Subsequently, private industry has applied the technology that NASA and DoD developed to provide telecommunications satellites for the United States and the World. During the early period of satellite development, the only company large enough to develop and pay for its own experimental satellite was AT&T. Now that AT&T has been broken up, there probably isn't one company left that has the mission or the money to take those kinds of risks now. And the ante has gone up too: today's experimental satellites are 10 to 20 times the cost of those first unsophisticated and relatively short-lived birds.

But that early government-sponsored technology phase has made us satellite suppliers to the world—up to now, that is. Hughes, for example, has built, or has contracts for systems for Canada, Indonesia, Australia, Mexico and Intelsat. Ford Aerospace has also built satellites for Intelsat and for India. Both those companies, and RCA, Astro-Electronics Division have built many satellites for U.S. government and commercial domestic systems.

This essential role of NASA has the support of government and industry leaders alike.

INTERNATIONAL ASPECTS

What are the international implications of falling behind? Consider the following, serious state of affairs within the International Telecommunications Union, the ITU:

Frequency allocations are the lifeblood of radiocommunication systems. In the case of satellite systems, it's frequency allocations and orbital locations that comprise the necessary resources. Both of these resources are in short supply these days, and the developing nations of the world know it. For several years, they have been showing their concern by seeking to have orbital locations and channel assign-

ments made to them. However, some of those countries may not need these assignments for many years—if ever.

But their basic concern is justified. They see the industrialized nations, the space powers, filling up the geostationary orbit. They also see us continuing to use other frequencies throughout the spectrum; frequencies that, in some cases such as the HF region, have been entered in the International Frequency List of the ITU since the earliest days of radio. All it takes is one look at the crowded orbital arc over the United States, and the list of companies who have applied to our FCC for new systems, to reinforce this concern of the Third World.

The developing countries now hold the balance of power in the International Telecommunications Union. The ITU is the specialized agency of the U.N. established to allocate the spectrum to radiocommunication services and to register frequency assignments to countries. It has always operated on the principle of one country, one vote. However, the number of member countries has nearly doubled since World War II, and all of the new members are from the Third World.

It's not only their aspirations and their sense of national pride that have grown since then. It is their real and demonstrable need for telecommunications services. In addition to these present needs, these nations of the world are concerned about their future requirements. Countries with a poorly developed domestic telecommunications infrastructure look to satellite systems, for example, as a way to provide telephone circuits and television channels to every corner of their territory without having to develop an extensive, terrestrial microwave network—often over difficult or impassable terrain. In the case of island countries, the more expensive alternative to satellites is an inflexible network of undersea cables. (Indonesia is an example of a developing and island country using a domestic satellite system effectively.)

In the past, the principle of obtaining a frequency, or an orbital assignment was "first-come, first-served." Now that's a fine principle if you're first, or if there are still suitable locations and channel assignments for your requirements when you apply. But if the cupboard is bare when you get there, it's not such a good principle.

The way that Third World countries have sought to assure themselves of "guaranteed access" to the orbit in future years, is through the adoption of detailed, a priori allotment plans. In such plans, the orbit/spectrum resource is apportioned among countries according to their stated—or claimed—"requirements". This apportionment can be made in perpetuity.

The ITU can establish such plans at Administrative Radio Conferences that it holds from time to time for different services. The Final Acts of those conferences become treaties, that we, among other countries of the world, are pledged to respect.

There have been several ITU conferences in recent years that have adopted such plans. The first inkling that the developed countries of the world could no longer run the ITU like an "Old Boys' Club" came at the 1974 Maritime Conference. It made assignments for shore stations to individual countries, some of which had no shore stations, no shore and no ships to communicate with. At the 1977 broadcasting-satellite conference, a detailed orbit assignment plan was adopted for the 12 GHz band for all of the world with the exception of the Western Hemisphere. This hemisphere put off its planning for several years, at the urging of the United States. But our turn came in 1983 when the nations of this hemisphere adopted a similar plan for our broadcasting-satellites. While our 1983 plan has a great deal more flexibility built into it than the 1977 plan, and while it could take advantage of the technological advances that had been made in the intervening six years, it's still an a priori plan with many of the drawbacks of such plans. What are these shortcomings?

The United States, among other developed countries, has been opposed to such plans, not because we are unwilling to share the precious resource of orbit and spectrum with the developing countries, but because we think that a priori plans are a terribly inefficient way to allocate the resource in both the short-term and the long-term. In the short-term, such plans will likely result in large portions of the resource which are assigned to some countries lying fallow, while the needs of other countries cannot be satisfied. In the long-term, such plans, which must necessarily be based on certain technological assumptions, will inevitably become outmoded and inefficient compared with the technology that could be employed if its implementation were not restricted or prevented by a rigid plan. An analogy would be killing the goose that lays the golden eggs. If we cut up orbit and spectrum now, we will limit our ability to make it produce more and more channel capacity by our increasingly more efficient use of it.

Not only have these several past ITU conferences replaced "first-come, first-served" with rigid plans for certain services and specific bands, the Third World called for—and obtained—a World Administrative Radio Conference, a WARC, to

consider what other space services and bands should be planned. This WARC will be held in two sessions, the first in 1985. It will decide which space services and bands should be planned, while the second, in 1988 will do the actual planning of the services and bands identified in 1985. Among the services that could be selected for planning are the Fixed-satellite service at 4 and 6 GHz, 12 and 14 GHz, and even higher frequencies such as the 20 and 30 GHz bands which are the focus of the ACTS Program.

What do we suggest instead? How do we propose to satisfy the desires of the Third World for "guaranteed access" and still use the orbit and spectrum efficiently?

Without giving the details of the alternative methods that we think are viable alternatives which should be considered by the 1985 Space Services Planning Conference, ORB–85, suffice it to say here that an important underlying assumption of all of them is that advances in technology will increase the effective capacity of the orbit and the spectrum and thus put off the day when there will be a scarcity of these resources. We've already seen that process at work in the fixed-satellite service. We've been able to increase the capacity of the orbit for such satellites through:

Frequency reuse: cross-polarization;
Shaped-beam satellite antennas with faster roll-off and lower sidelobes;
Better earth station antennas: lower sidelobes;
More efficient modulation methods: digital transmission;
Demand assignment;
Digital speech interpolation and;
Use of higher frequency bands.

As a consequence, the number of channels we can now derive from a satellite using the entire 500 MHz allocated at 4 and 6 GHZ or at 12 and 14 GHz has jumped dramatically. Morever, these satellites can now be placed closer together. (The FCC just recently ordered two-degree spacing in place of the 3½ to 4 degrees heretofore.) We will have to demonstrate a continuing commitment to the development of still more advanced technology to give concrete assurance to developing countries that they will have orbital capacity available to them when they need it.

If we don't fill this technology and telecommunications gap, who will? If we don't convince the Third World that we're committing our research and development skills to increasing the effective capacity of the geostationary satellite orbit and the spectrum, how can we tell them that they needn't worry about not having their country's name on parking slots in space?

Recall that Japan and Italy, among other nations, are actively developing the 20/30 GHz band. Moreover, we have recently learned that those very countries hope to develop that band with the help of some of the same technology that would have gone into the ACTS Program. Motorola has reported that it was approached by representatives of both Japan and Italy to have Motorola go forward with the development of the ACTS baseband processor—but that it would be done under foreign sponsorship. This is confirmation that other countries are serious about developing technology for the needs of 2001. The consequence of another country perfecting or acquiring the technology for highly efficient, on-board processing, is not only that we would lose leadership in the space segment to supply domestic and foreign requirements, but that we would also fall behind in mastering the technology bo build and supply the matching, equally advanced earth station processors and ancillary equipment. How much of a market will there be for earth stations that will be employed in commercial follow-ons using ACTS technology? The market is estimated in the thousands. That is because one of the features of the high-power, very narrow, rapidly scanning spot beams to be developed by ACTS will permit the use of a large number of smaller, less expensive earth stations than are used in present-day satellite systems.

A look at the past may be instructive. The last time NASA abandoned communication satellite flight programs, it was as the result of the 1972 decision which assumed that industry investment in technology would be adequate to maintain U.S. leadership in the field. But the following example illustrates how evanescent such leadership can be. Recall that NASA had supported the development of a 200 watt, 12 GHz, TWT by Litton Industries, that made the CTS/Hermes the world's first high-power broadcasting-satellite, and demonstrated that one could pick up television signals from space on a receiver with a small antenna, and that one could generate a spot beam and point it towards Appalachia in the morning, the Rocky Mountains at midday, and Alaska in the same evening. But CTS/Hermes was the end of that line. Where are the eight U.S. companies recently approved by the FCC to construct broadcasting-satellites going to get their TWTs? The only two sources now are Thomson-CSF in France, and AEG Telefunken in Germany. In both cases, development of these tubes was supported by their respective governments. And

where has an even larger TWT been developed? Telefunken has produced a 750 watt, 12 GHz tube—also with government support.

Still another example is the receivers that will be used with U.S. DBS systems. Japan was one of the countries that filled the vacuum after NASA was compelled to abdicate its role as the agent of the U.S. responsible for our leadership in satellite communications. It was Japan that operated the next broadcasting-satellite system. Even though their first spacecraft was built by the General Electric Company at its Valley Forge Space Center, and launched by NASA, the Japanese government paid for its development—and for access to the technology that went with it. Japan also funded five of their receiver manufacturers to develop receivers to be used with the system. Now, with their experience, those companies are ready to, and capable of, supplying U.S. and European markets with receivers for the coming DBS systems. No U.S. manufacturer is so favorably positioned. (Moreover, the Japanese content will climb to about 64 percent at the end of the next series of broadcasting satellites now under development. They will also launch their own satellite on their N-I and N-II vehicles, exact copies of the Delta launch vehicle, built under license from McDonnell Douglas.)

ACTS RELATIONSHIP TO MILSTAR

One of the questions that has been raised regarding the need for the ACTS satellite is the possible alternative of using technology spin off from the DoD MILSTAR program. MILSTAR is a narrow-band, low data rate system, providing "gracefully degradable" jam-resistant, teletype and low-grade voice circuits to a limited number of users. A comparison of ACTS systems characteristics with MILSTAR is included as Attachment 3. It will employ spacecraft design features that emphasize its military mission including components and subsystems that provide hardening against attack in space. These are not the system objectives that are essential to the highly-competitive, international telecommunications marketplace, where effective spectrum utilization is a major consideration. Thus, the MILSTAR program will contribute to our understanding of frequency-specific component development but it will not substitute for the type of systems and technologies that are appropriate for commercial applications.

SUMMARY

In the ACTS Program that resulted from NASA's competitive procurement—a team of RCA, TRW, Texas Instruments, Comsat, Motorola, GE Valley Forge, LNR, Scientific/Altanta, ITT and Hughes are ready to develop the space and ground hardware. In addition, more than 50 experimenters (universities, earth station manufacturers, and potential users such as the U.S. Postal Service and hospital associations, etc.) are scheduled to participate at their own expense, estimated at about $50 million. The total investment in ACTS, expected to be about $500 million over the duration of the program, is too much for one company to afford, too much for one company to risk. NASA has a Congressionally mandated role to ensure U.S. leadership in space technology and the ACTS program is an important element in carrying out this role. It will provide the knowledge and, more importantly, the practical space experience with frontier communications satellite technologies. Our experience has indicated that these technologies will be needed and that our foreign competitors are seeking a technological edge that will position them to become preferred suppliers of such advanced systems.

Mr. Chairman, we support restoration of funding for the ACTS flight program in the fiscal year 1985 NASA budget.

Thank you for the opportunity to bring these views to the Committee's attention. I will be pleased to answer any questions you may have.

ATTACHMENT 1.—STATEMENT OF DR. ALBERT WHEELON, SENIOR VICE PRESIDENT AND GROUP VICE PRESIDENT, HUGHES AIRCRAFT, BEFORE THE 4TH WORLD TELECOMMUNICATIONS FORUM IN GENEVA, SWITZERLAND, OCTOBER 1983.

The enormous potential of communications satellites operating at 20 and 30 GHz (i.e., Ka band) has been apparent for a decade. People were first attracted by the large bandwidth allocation. With the small wavelength, they could also imagine forming multiple beams with modest antennas and using this band over and over. What was not known was the extent of signal attenuation in the atmosphere . . .

Several American companies have recently applied for authority to use the new band. A number of satellite systems are already planned by other countries. Japan launched its Sakura-2 satellites this year, each of which carries six Ka band tran-

sponders served by 6-watt travelling wave tubes. Italy is planning a domestic satellite system that will provide redundant transponders with 20 and 30 watt amplifiers. Germany's Postsat system will have a 20/30 channel. NASA is planning an experimental satellite, ACTS, which would demonstrate 20/30 GHz communications and sophisticated baseband signal processing/switching techniques.

My belief is that 20/30 GHz will eventually become an incredibly valuable communications resource. Our frustration so far has been in trying to make KA band do traditional jobs. I believe that commerical systems using the new band will appear in the 1990's. It will be used for new services, such as teleconferencing and non-real time video transmission. These require very large bandwidths and can stand the occasional outage (3.5 hours per year) of 20 dB or more. In the meantime, the basic components for receiving at 30 GHz and transmitting at 20 GHz are being developed in government-supported programs.

ATTACHMENT 2.—COMPARISON OF ACTS VERSUS HUGHES—KA-BAND SATELLITE

In recent filings to the FCC (November and December 1983), two companies, American Satellite and Hughes Communications, have initiated a move toward commercial use of Ka-band frequencies as part of their planned communications satellite systems. Although both of the proposed systems are significant advancements in satellite communications, the Hughes system, a large Ka-band satellite to be launched in 1988, represents a substantial increase in satellite capability. Because of this, it is appropriate to review these planned advancements as they might relate to the technologies in ACTS.

The Hughes satellite is a very high capacity system when compared to today's conventional satellites. It is larger by a factor of 4 in capability than the largest satellite in service today and is an extrapolation of current FDMA technology to Ka-band frequencies. Spacecraft demodulation and remodulation techniques will be used to improve the link capability and enhance the use of small earth terminals.

Conversely, ACTS is an experimental communications satellite system targeted on developing the advanced, high-risk technologies needed to enable operational systems of the 1990's. The critical technologies to be developed involve very high gain scanning multi-beam antennas, on-board signal processing and switching at both baseband and intermediate frequencies, and time division multiple accessing of the satellite resources. These technologies will permit efficient utilization of the orbital arc/spectrum resource at all frequency bands and enable continued growth in satellite communications service.

To facilitate a comparison, Table I lists the technology implications of the proposed Hughes system technologies related to those in ACTS. Major differences in access techniques, coverage, spectrum efficiency and system flexibility are indicated.

TABLE I

	ACTS	Hughes satellite
Access	TDMA	FDMA/TDM.
Traffic accommodation	Dynamic	Fixed.
Coverage	Conus	Limited.
Effective frequency reuse	Greater than 6	Less than 3
Orbit spacing	1°	2°.
Adaptive rain fade compensation	Yes	No.

Because of these technology implications, limiting advances in technology to the level of the proposed Hughes system will constrain the arc/spectrum efficiencies and growth potential of future satellite systems far below the capabilities permitted by ACTS technology.

A review of the spacecraft antenna characteristics (Table II) indicate a similar approach to antenna geometry exists, but the reconfigurable beamforming network and scanning beam system of ACTS is a major technology advance. The increased demand on antenna performance by the ACTS requirements is also indicated.

TABLE II

	ACTS	Hughes
Type	Dual	Dual offset Fed.
Beam forming network	Reconfigurable	Fixed.
Fixed	30 to 100	16.
Scanning beams	6 for Conus coverage	0.
Isolation:		
Spatial	Yes	Yes.
Polarization	Yes	No.
Time	Yes	No.

Only ACTS allows buffering on the spacecraft to facilitate processing of the uplink and downlink signals and allows switching and routing of data rates down to a single voice channel. High rate demodulation of ACTS permits use of significantly lower parts count on the spacecraft. The increased flexibility of the ACTS baseband processor will allow freedom of choice as to system response to changing traffic patterns in operational systems.

TABLE III

	ACTS	Hughes satellite
Uplink and downlink buffering	Yes	No.
Demodulators:		
Type	Burst (TDMA)	Continuous (FDMA).
Rate (MBPS)	27.5 and 110	1.5.
Numbers required	100's	1,000's.
Baseband processing	Yes	No.
Baseband circuit routing	Multiples of 64 KBPS	1.544 MBPS only.
Adaptive rain fade compensation	FEC and burst rate reduction	None.

In Table IV, a limited comparison is made of the matrix switch technologies of both systems since only limited information was available in the filing. Fundamentally, the ACTS switch will allow a dynamic response to assigning channels in response to satellite traffic and is based on the very fast switching capability of GaAs FET's.

TABLE IV

	ACTS	Hughes satellite
Reconfigurability	Dynamic	Static.
Matrix size	Comparable	Comparable.
Switch speed	20 nanoseconds	Unknown.
Switch technology	GaAs FET	Do.

In summary, although the Hughes satellite is a significant advance in many ways over currently operating commercial satellites, it does not duplicate, in any significant way, the technologies in ACTS. The proposed Hughes satellite is very similar to the planned Italian satellite proposed for launch in 1986. Development of ACTS technologies including fixed and scanning beam antenna systems with baseband processor systems is still needed for the advanced satellites of the 1990's.

ATTACHMENT 3

COMPARISON OF MILSTAR AND ACTS FEATURES

Item	Milstar military 44/20	NASA ACTS program
Beams	1 to 4 (steered uplink and scanned downlink).	20 fixed 6 scanning.
Beamwidth	1° to 2°	0.3° or 0.45°.
Beam coverage	Full Earth	Patial Conus.
Maximum aperture size	4'	10' to 14'.
Maximum power (W)	20 Via solid state	40 to 80 via TWT.
Antenna approach: Downlink, Uplink	Phased array reflector with folded optics and beam nulling.	Reflector with folded optics.
Physical survivability	War fighting environment	Natural radiation.
Frequency	44/20 GHz and UHF	30/20 GHz.
Terminal capacities	<16 KBPS	1 to 500 MBPS.
Terminal type	Mobile	Fixed.
System capacity	<1 MBPS	4 to 10 GBPS.
Availability	0.98	0.995 to 0.9999.
Rain compensation	Fixed margin	Power augmentation, site diversity, and forward error correction
Access	FDMA UP/TDM (Time Division Multiplexing).	TDMA.
Special processing for antijam and LPI	Spread spectrum, frequency hopping, antenna nulling.	None.
Switching and network control	Few number of circuits via satellite baseband processor.	20x20 If switch matrix with 100,000 circuit capacity 60,000 circuits via satellite baseband processor.

Senator GORTON. Thank you very much.

Mr. Fthenakis.

Mr. FTHENAKIS. Mr. Chairman, distinguished members, I am really very pleased to have the opportunity to discuss with you today the ACTS program. During the last 25 years, I have been very deeply involved in the development of satellite communications systems, both military and commercial; had the opportunity to look at that field from both ends—building satellites, building spacecraft, building Earth stations—and from the other end, in creating a common carrier—American Satellite—which is one of the first common carriers, to start operations in 1974.

For the last decade, I have had to go through the process of integrating the technology, the financial aspects, as well as the marketplace. So I view what is happening today from that experience. I can attest to you that the experience of creating a company that tries to serve the public, serve the end-to-end user, not just provide technology, is really an awakening experience. My remarks will be very much colored from these experiences that I had during the past few years.

By the way, American Satellite is the first satellite carrier to apply to the Federal Communications Commission to utilize the 20/30 GHz, Ka-band. We have an application pending in conjunction with the other bands. Our initial effort, of course, is slightly experimental, but we do not claim we can do what the ACTS program or the Hughes Galaxy program can do.

Looking from the standpoint of a company that will provide public telecommunication services, among these programs—the Hughes Galaxy program, or the ACTS program, or the Milstar pro-

gram which also utilizes Ka-band—it is obvious that the Galaxy program or the military program will be of little use, if any, to a carrier like American Satellite or anyone else that tries to provide such public end-to-end service.

Take the Hughes proposal, for example. This is a very ingenious space segment that has been proposed. As a matter of fact, I would say very ingenious, very competent, very clever configuration. It takes advantage of very specific orbital spots and specific combinations of the old FDMA, the analog scheme of transmitting information, and the more advanced scheme, TDMA, for transmitting digital information. That combination has been very smartly configured to have inexpensive Earth stations, and yet not to suffer the characteristics of the known limitations of the output power amplifiers of the satellite. But that is what it is; it is a very cleverly configured space segment. It is missing, really, the objective that the ACTS program had.

The ACTS program was built with a number of blocks, a number of developments which a carrier or a user, wanting to provide a service, can take and put together in various configurations and satisfy the end-to-end requirements of the public to be served. You cannot get a given configuration and say, OK, that is it, and then live with that configuration for every need.

The market is very diverse. The requirements are very diverse. In order to be able to satisfy them, you must have the flexibility to take those boxes, wherever they have been developed, and put them in the right configuration and provide that end-to-end service. This, for me, was the biggest advantage of the ACTS program—developing those intrinsic technologies and black boxes to allow this flexibility.

In addition, there are a couple of things, very critical, that you cannot experiment with on the ground. And I will mention what they are. No. 1 is the end-to-end synchronization. The verification of this sophisticated technology, the synchronization in a split second—I am talking nanoseconds—is not a simple task. You cannot adequately simulate it on the ground. You have to resolve this problem by space experimentation. The Galaxy program does not even approach this subject.

Second, the problem with the Ka-band is excessive fade. That is, the weakness of the signal because of rain, where a rain condition exists. Now, the ACTS program had incorporated a process for fade compensation either through forward error correction or gain increase. Again, that is not a technology that you can test and verify on the ground. You have got to go through the actual space links, the actual orbital performance, to see how effective you are.

I would say, these two experimental results, would have been the major contribution of the ACTS program to the development of total systems. They would have subtantially enhanced the ability of a carrier to develop and apply various configurations, and not to have to live with only one configuration.

Let us also examine one degree further down from the system level, the black box level. Let's take one box, the processor, the base band processor. The one that is developed by the ACTS program is very fundamental. It works and switches at the single telephone line level, the 64 Kbps, so that it gives you substantial flexi-

bility. The one of the Galaxy is far away from doing that. It is a bulk switch. And if I were to make a comparison, I would talk about a slow bulk processor versus a very versatile, fast, single telephone line capability. The ACTS processor fundamentally, is one of the key elements required for providing public communication service. It offers the ability to configure many diverse configurations for the many required services.

Well, I can go on and on and examine these differences. But in my mind, from the standpoint of providing service to the end user, to the public, the ACTS program had a subtantial number of advantages. In addition, the techniques that experimentally would have been developed, cannot be developed on the ground; I can attest to that.

There is no question that the Galaxy proposal is a very aggressive proposal, in addition to Milstar, the military program, progresses the technology. But the objectives of these programs are entirely different from the objectives of the ACTS program. One is to provide very secure communications; the other is really to sell transponders and in this way make money.

By the way, I would like to mention that the date and voice network capability via satellites, was developed by organizations that didn't just sell transponders for cable TV; these organizations spent a lot of money in developing voice and data networks. In the first generation of satellite communications systems—American Satellite, Western Union, RCA, SBS—spent over $3 billion to develop message network capabilities and they did not make a single penny in monetary profit from these services. These services should be the No. 1 long-term national telecommunications capability objective.

The second generation systems which is coming up—it started in 1981—has begun to show some profit. During those tough recent years we had in our economy, I think the satellite carriers carried the torch, investing and losing money but developing the satellite telecommunication capability.

Take as an example another carrier, SBS, which is still losing money in trying to provide data and voice networks. I think that the problems of networking, of providing the long-term sophisticated telecommunications services are the fundamental problems that we have to solve. I do not believe—and I will concur with Mr. Gould here—that any carrier can afford to put the investment—put the orbital tests to resolve these problems and satisfy the national needs of the 1990's.

Now, do we have a national need? I think we do. If you look at what is happening in our economic development these days, the computer industry and the telecommunications industry have joined together in what we call the information industry. This industry really employs more than 50 percent of the working force of the United States. It is a substantial part of the national economy, and satellite communications is a substantial part of that industry.

I do not think we can afford to turn our head back and say we are not going to support this segment in the future. If we do, I think we are going to live to regret it. And this is my last closing statement.

Senator GORTON. Thank you very much.

[The statement follows:]

STATEMENT OF EMANUEL FTHENAKIS, SENIOR VICE PRESIDENT, FAIRCHILD INDUSTRIES

Mr. Chairman and Distinguished Members of the Subcommittee: I am very pleased to have the opportunity to testify before your subcommittee during these hearings on the fiscal year 1985 budget for the National Aeronautics and Space Administration and more specifically on the Advanced Communications Technology Satellite (ACTS) Program.

During the last 25 years, I have been deeply involved in the development and deployment of communications satellite systems, both military and civilian. In addition, as a senior vice president of Fairchild Industries, I have also been deeply involved in the creation and management of American Satellite Company, on of the three initial U.S. satellite common carriers commencing service in 1974. Incidentally, American Satellite is also the first satellite carrier to apply to the F.C.C. for a permit to initiate service in the Ka band, that is the 20/30 GHz frequency band—the band under consideration in the ACTS Program and the recent Hughes Communications Galaxy proposal. A close examination of the developments contemplated by the ACTS Program versus such programs as MILSTAR and the Hughes Galaxy proposal reveals that the former would be of immense value to future programs required by various carriers such as American Satellite while the latter would be of very limited value, if any at all. And it is easy to see that, in general, this would be true for most of the services to be offered by domestic satellite carriers in the Ka band or other bands. A few comparisons will demonstrate this point.

The Hughes proposed space segment is, in fact, a very competent and clever configuration which takes advantage of specific orbital locations and a specific combination of a FDMA uplink and TDMA downlink that optimizes a special case of transmission. But that is essentially all the Hughes proposal amounts to: a specialized space segment with limited, special characteristics. It does not provide building blocks with the capabilities necessary to enable carriers to synthesize the wide variety of end-to-end communications systems for optimizing the multiplicity of services required by U.S. users. The ACTS Program, on the other hand, develops a number of such building blocks and attempts to solve a number of fundamental general systems problems, many of which can only be solved through actual orbital tests. End-to-end synchronization techniques—techniques which would enable carriers to configure a variety of end-to-end systems to support the diverse telecommunications requirements of the public—require split-second (nanosecond) performance and can be developed only through actual orbital tests. Similarly, compensation for signal fading due to rain is another technique which can be effectively developed only through orbital tests. Since the loss of signal and the introduction of burst errors is a serious weakness of the Ka band spectrum, actual in-orbit testing of the synchronization and fade compensation techniques is essential to achieving effective utilization of this Ka band spectrum in the future. the ACTS Program proposes just such tests.

Additional evidence of the superiority of the ACTS Program is provided by a careful comparison of its proposed technological innovations versus those of the other programs. An on-board baseband processor, for example, will be one of the critical building blocks of any advanced, future system. The Hughes proposal utilizes an on-board processing scheme that is quite limited due to the routing of preselected traffic on command by customer request, without the ability to operate and obtain routing at the single-telephone-line level. On the other hand, the ACTS Program utilizes a dynamic, real-time traffic routing scheme at the 64 Kbps (i.e., simple telephone line) level. The comparison is that of a slow, manual, bulk-use system to that of a high-speed, automatic-at-the-line-level, real-time, versatile system. Moreover, the ACTS on-board baseband processor development is such that it can be used as a building block in a large variety of configurations, allowing the needs of the market and user to determine the specific configuration. Another factor: the Hughes proposal, according to my understanding, employs silicon—today's technology; the ACTS Program would use gallium arsenide (GaAs)—tomorrow's technology.

A second example of an unresolved technological item in these proposals is that of frequency re-use. Both systems employ a technique that has been extensively used in the past, namely, spot beams. This technique results in spatial diversity and the ability to re-use bandwidth several times. However, this ability to re-use the bandwidth is not of great importance from the communications viewpoint. What is critical is the amount of information transmitted through this multiple-used bandwidth. The Hughes 160 MHz transponder transmits 150 Mbps; a simple calculation (dividing 150 by 160) reveals that this is less than one bit per Hertz. Present communica-

tions schemes using the same digital signaling, i.e., QPSK, transmit two bits per Hertz. One can consequently see that the amount of information transmitted through the 160 MHz transponder is not especially efficient.

I do not want to be misunderstood. The scheme proposed by Hughes is indeed very clever: by not passing a multicarrier spectrum through the power amplifier, it avoids the TWTA non-linearities on the uplink and allows the use of simple and inexpensive FDMA uplinks; the TDMA downlink allows full use of the TWTA power. However, since this approach does not require split-second, end-to-end synchronization, it will not develop and demonstrate this critical technology. This technology, applicable both to Ku and C band systems, may very well be the most important technology to result from the ACTS program.

Most definitely, neither the MILSTAR nor the Hughes Galaxy proposed technologies will establish the U.S. as the world leader in the field of public satellite communications. Although very aggressive programs, this is not their objective.

Furthermore, I do not believe that it is possible for any one industrial organization to underwrite the expense of achieving the broad, national objective—an objective that can only be achieved by developing advanced technologies requiring sophisticated orbital testing. The non-government-sponsored attempts will inevitably fall short of meeting this urgent national need. And indeed it is an urgent national need. I would like to reiterate some of my thoughts expressed in previous testimony.

The first-generation communications satellite systems were established during the 1974-1981 time period with the more sophisticated second-generation systems starting to replace the old generation in 1981. Construction of these second-generation systems is presently in high gear and is scheduled to continue into the 1985-86 time frame.

The U.S. domestic satellite industry has expended over $2 billion in the 1974-81 period with an additional $3 billion expenditure anticipated for the establishment of the second-generation capability. It is interesting to note that the over-$2 billion investment by U.S. industry in the 1974-1981 time period did not generate any worthwhile, monetary profit. The funds expended were mainly used for developing the end-to-end service capability and were divided approximately equally among three major areas: service application, establishment of the communications plant, and R&D. The sale and auction of transponders, mainly for cable TV industry, is the only area that has generated appreciable profits. Of course, this use of space for cable TV hardly satisfies the long-term telecommunications requirements.

As we all know, the communications industry and the computer industry are rapidly merging into a common information, generation and transmission industry. Today more than 50 percent of the U.S. work force is associated with the information industry, and this percentage is rapidly increasing. The information industry is becoming the major and most vital segment of the U.S. economy. Satellite communications is playing a major role in this important segment of the economy. In addition, it represents one of the few areas in which the U.S. is still the world's leader. As I mentioned previously, during the recent years—a period of difficult economic conditions—U.S. industry carried the load in this field with heavy investments as well as heavy losses. Only recently have some of the U.S. satellite communications carriers started to show a profit by operating telecommunications networks. In addition, each of these carriers has committed to additional heavy investment—collectively amounting to several billion dollars—to be expended in the next three to five years. These investments are absolutely necessary if this industry is to survive and become viable.

In view of:

1. The size and importance of the segment of the U.S. economy which includes communications satellite services;

2. The size of the U.S. work force involved in this segment of the economy;

3. The need to maintain our present leadership position in this field against strong competition supported by foreign governments;

4. The efforts and investment by U.S. industry to establish the field of communications satellite services as a viable economic venture.

I think NASA should be very actively involved in assuring the long-term leadership of the U.S. in the field of communications satellites for public use.

However, I would like to candidly express some of my concerns regarding the ACTS program. I think NASA should have been more serious and flexible in its attempt to actively involve operating satellite carriers in the ACTS orbital test program. Such participation of satellite carriers should have been a major and integral part of the project, with specifics included in the program plan. It proved to be difficult for carriers to utilize the system on a permanent basis due to the fact that the program, although offering a space segment with limited life expectancy and no

backup, demands the early deployment of expensive, specialized ground segment facilities. In spite of this difficulty, the companies with which I am associated developed a concept under which, with some limited investment on our part, we could participate in the program and fulfill some of these additional objectives. Unfortunately, the procurement was so structured that such participation was extremely difficult.

I will close my testimony by repeating my strong belief that if the United States government withdraws from aggressively supporting our nation's technological leadership in the area of communications satellites, we will live to regret the decision.

Senator GORTON. Dr. Young, I would like to start with your statement in your testimony that since 1973, when NASA's satellite communications program was drastically phased down, the U.S. satellite communications industry has been bypassed in some areas by foreign competition.

What are those areas, and what has been done or is the process of being done to regain that lost lead?

Dr. YOUNG. We have perhaps dropped behind, Senator Gorton, in several areas. We have already seen development of direct broadcast satellite receivers, for example, in Japan taking the lead internationally on that front. And certainly the Japanese, at least temporarily, have a leg up on development of technology appropriate for the 30/20 GHz band, as well as computer technology and what we would call final mile technology associated with satellites.

Interestingly enough, the Italian Government is also very aggressive now in terms of looking at the higher frequencies and, with their Italsat satellite, will be experimenting in those bands.

I think that the problem that we see particularly is one not only for the satellite industry as the builders of satellites, but for people who are in the ground terminal business and in associated component technology. Therefore, the question about what is being done is certainly appropriate.

I think that in the last 2 or 3 years, NASA has tried to do a couple of things. As I believe the committee knows, I also serve on the Space Applications Board, and it has been largely due to some of the studies and the results of those studies from the National Research Council and Space Applications Board, that NASA has taken another look at applications.

The development of the ACTS program is clearly one way to help U.S. industry recoup. Another way is in their basic research and analysis program which is the development of small, discrete pieces of technology, which are integratable into any commercial system. And I think the recent signing on the agreement on a Mobilsat program with Canada is definitely a step in the right direction. It is an optimal step, because it will involve United States and Canadian industry, involve some technology transfer, but it does not give away our technology to a foreign government.

However, those efforts have been very recent and, we think, very much underfunded; and with the possible demise of an ACTS flight program, I think it is very real that we are turning over the possibility of that type of satellite technology development to foreign sources.

I would just like to follow up with a word about the Japanese. Several of us have spoken of that today. In a recent article in Aviation Week and Space Technology, it was quoted as saying that the

Government in Japan's policy favors development of Japanese technology and phasing out of all overseas hardware purchases.

It is very clear what they are doing. They want to buy in-house, and they are going to develop the industry to meet that need.

Senator GORTON. Mr. Gould.

Mr. GOULD. Thank you, Mr. Chairman.

If I can add a gloss to what Dr. Young has said, her mention of Italy and Japan and their technology development reminds me that in addition to developing this technology on their own, which they are certainly capable of doing, they seek it wherever they can find it. It has been reported recently by Motorola, one of the companies that was to have been a member of the team of some 15 contractors and 50 experimenters as part of the ACTS program, that they were approached by representatives of Italy and Japan to develop the baseband processor that Motorola would have developed under the ACTS program. However, Motorola was now being asked to do this work for the Italian and the Japanese space programs.

Thank you.

Senator GORTON. Mr. Fthenakis will comment.

But I would like you to answer another question while you are commenting on that one. And that is, whether or not you think an ACTS ground test program would, to any extent, enable the United States to meet these Japanese and European challenges?

Mr. FTHENAKIS. I want to add something to the question you had for Dr. Young, a very simple answer from actual experience.

Our company through a subsidary—works on an over $2 billion satellite communications program for the United States, the TDRSS program. This is a very valuable program. One of the key components of that is the 20 GHz traveling wave tube. Unfortunately, we had to purchase that tube from Germany—Telefunken—in a vital U.S. program.

To give you another example, last year, American Satellite undertook to develop a very up-to-date technologically specialized network for one of our insurance companies; that is, Allstate. We wanted a very fast TDMA system. We gave two development contracts, one to a U.S. company, who finally had to default. We eventually bought from Fugitsu in Japan.

So my experience is that, yes, we get, even today, substantial technological elements from overseas, and we let ourselves get behind.

What was the second question?

Senator GORTON. The extent to which a ground test program would have a positive impact on this competition.

Mr. FTHENAKIS. I think it will have a positive impact. The ground program will develop elements, and has developed elements that will be very useful in the future. But we should never lose the perspective that we really want to develop—the things that the industry cannot develop and these are the things that will take very expensive orbital testing. The satellite equipment industry could develop by themselves—it is conceivable—a very expensive orbital testing program to test system parameters like the synchronization. But I do not really think that there is any industrial outfit that will be able to afford that.

Senator GORTON. Dr. Young, back to you.

It has been suggested that NASA's ACTS program does not test generic techologies, but instead focuses on a specific emphasis and direction which is not drive by a satisfactory need.

Your comment?

Dr. YOUNG. Senator, I have sat at this witness table with members of industry, as I am today, 2 years ago and have interacted with them in the interim period, and other than perhaps Hughes itself which, interestingly enough, 2 years ago, as we have already heard, testified that there was a need for ongoing Government support of this type of technology, everyone we have talked with in the industry believes that the technology development under the ACTS program is entirely appropriate for the type of marketplace that will exist in the 1990's, which is one—as Mr. Gould has already mentioned—which involves scarcity of spectrum, the need for the development of new component technology which meets that need, and all the recent studies that we have seen, including the one in preparation for the recent work, would tend to support that observation.

NASA has periodically convened its own committees, and there has been an industry user group working on the ACTS program as an advisory committee since its inception. This has been a completely open committee which has involved carriers, manufacturers, and others.

And from the inception of the program, there has been unanimous support that the technology is required. So I really think that any argument that NASA is not addressing a real marketplace is simply not supported by the evidence.

Senator GORTON. To sort of try the reverse of that question for you again, Mr. Gould. It has also been suggested that the technologies of the Hughes Galaxy filing, along with those of the yet to be developed Milstar and Intelsat VI, will provide most of the technologies offered by the ACTS flight test program.

Would you comment on that, both generally on the usefulness of those technologies in a commercial environment, and what happens if Hughes, Milstar and Intelsat do not carry them on?

Mr. GOULD. Yes, sir.

To start with, Milstar is a military communications satellite program which Hughes has under contract with the Department of Defense. That contract will be the source of much of the technology for its commercial FCC system application. But that technology is being developed for very different communications objectives and is intended to function in a very different environment.

The environment of military communications is hostile, both in the jamming sense and the physical sense. Milstar will be hardened to resist physical attack, which makes it inefficient, costly, and heavy. The communications requirements are for low data rate, highly secure communications, protected from jamming, not at all the requirements of a commercial operator.

Traditionally, not very much of the military hardware and military techniques are applicable in the commercial world.

The Hughes Galaxy 20/30 GHz commercial program which will be derived from Milstar, meets immediate requirements, using today's miracles. Today's miracles are not enough for requirements we know will exist in the year 2000.

If I could add one comment on the 200-watt tube that Mr. Fthenakis mentioned. It is available from Telefunken, and also from Thompson CSF in France. However, that tube was born in the United States. It was developed by Litton Industries for the CTS/Hermes program under NASA sponsorhip. It was one of the last developments in the communications area that NASA sponsored before it was taken out of the flight program business in 1974.

Development of such tubes was taken over by Europe, which is the only commercial source now. Telefunken, by the way, also has a 700-watt tube, that it developed with Government support.

Thank you.

Senator GORTON. In response to the last question, most of the testimony we have indicates that ground testing fails to provide the necessary degree of confidence for operators to implement these technologies into their systems.

If this is true, to what extent will these ground-tested technologies become operational in American systems, and compared to technologies that are flight tested, what kind of delays are likely in the implementation?

Mr. FTHENAKIS. Well, if you are a commercial operator and you are about to spend $250 million or $300 million to develop a satellite system—a recent application of American Satellites is a $250 million application—obviously, you cannot afford to take the chance if something has not been tested in space. You cannot just throw, as a firecracker, that kind of money up there.

So for new technology that has not been flight tested, the application would be really not forthcoming and people will try to live with the old technologies. Eventually, I think the new technology is going to find its way to flight testing. But if we do not do it through a U.S. Government-sponsored program, I think it is going to find its way to flight testing in some European or Japanese program. And then we are going to go and buy that equipment from there.

I told you we just bought a Japanese TDMA last year. It pained me in the heart to do that, but we had no alternative.

So it will eventually find its way up there, and be tested in orbit, but probably through the Europeans or the Japanese.

Senator GORTON. Dr. Young, the Hughes Galaxy system provides a fixed beam technology for 16 U.S. metropolitan areas, while the ACTS flight program provides a scanning beam technology which covers the whole country.

What is the importance of this scanning beam technology, and is it being developed under the aegis of any other American company or organization, or by any foreign competitor?

Dr. YOUNG. Mr. Gorton, we feel that the scanning beam technology is probably one, along with the base band processor, of the two critical technologies in the ACTS program. There are several reasons for this.

First of all, the ACTS program provides for fully time division multiple access up and down on the satellite, which the apparent Hughes filing does not. This means that very small or very large amounts of data will share the time on the transponders and be switched in real nanoseconds, which is very difficult to do, but also very important, because it means that information can be moved

from one location to another, not just among major metropolitan areas.

I have had the privilege of traveling a little bit in your State of Washington over the years, and I know, for example, that the need for data transmission to and from a city like Pullman is perhaps a lot less frequent than in Seattle. But with a scanning beam technology, a beam could dwell over Pullman for a fraction of a second, and yet dump down enough data for Washington State University to meet all its agricultural needs for a year. That is rather impressive technology.

We, of course, represent a variety of users, many of whom do serve their constituents in rural and sparsely populated areas. But equally, I think we need to be concerned about small business. And one of the ironies to me about the discussion going about the ACTS program is the ACTS program is exactly the type of technology which was most appropriate for small business use, and yet that is the community that is most likely to be hurt if there is no test of the program and if there is no scanning beam technology.

Now, in terms of what else is being developed, to the best of my knowledge, other than U.S. team members who have been under contract to NASA in the developmental stage of the program, the scanning beam technology would not be available immediately or under the same timetable. It is quite possible that eventually the Japanese, the French, the Germans, or the Italians might be able to develop the technology, probably the Japanese first.

Senator GORTON. Mr. Fthenakis, according to some of the testimony we have, one of the most critical technologies of the ACTS flight program is the base band processor which can act as a switchboard in the sky, as it were.

What other military and civil flight programs will test this high-speed base band processor?

Mr. FTHENAKIS. I am not aware of any program that will do that.

Senator GORTON. Military or civilian?

Mr. FTHENAKIS. Not at that level, that is with the versatility of the ACTS program. I know of some ground programs. We at American Satellite have a program which cost us about $30 million in development, doing just that on the ground. But for ground application in conjunction with the Earth stations, resulting to a very expensive system. If we had one switch in space, we will have our system cost reduced by a factor of 2 or 3. A much more cost-effective system.

Senator GORTON. As sort of a summary of what all of you have said, how much private industry investment has been made in the ACTS program, and what will be the impact on industry's confidence in doing business with NASA if it does not fly and has only ground tests?

Mr. FTHENAKIS. I really cannot answer the first question, how much investment.

Senator GORTON. Can either of the others of you?

Mr. Gould.

Mr. GOULD. Thank you, sir.

It has been estimated that the experimenters would have invested some $50 million and the contractors would have invested an-

other $50 million of their own research and development not reimbursed by the contract with NASA.

Dr. YOUNG. We essentially believe those numbers correlate. And to add just a footnote to that, 2 years ago, when OMB insisted that if the program go forward, there be cost sharing, the team that ultimately would have signed the contract has already agreed to do that, and tightened their belt to some extent, and we certainly expect there will be considerably more cost sharing if there is an experimental program, because the experimentors have to provide their own terminals.

Senator GORTON. Why don't you go on to the second half of my question, then? Any of you.

Mr. Fthenakis.

Mr. FTHENAKIS. If I understood correctly the second half, I think that the carriers will be willing to spend money, and substantial money, in implementing the rest of the technology that will develop from the ACTS program. I know we would. But certainly we would not be able to afford a thing like an orbital test.

Senator GORTON. Frank.

Senator LAUTENBERG. Thank you, Mr. Chairman.

Senator GORTON. Do you have an opening statement? We will enter that.

Senator LAUTENBERG. If I might, a short statement. I would like to be clearly on the record, and I want any of the people in the room who may have an interest to understand where I am coming from, as they say.

I am pleased to participate in this, our third day of hearings on the——

Senator GORTON. I was not sure what your position was.

Senator LAUTENBERG. I know, but when Dr. Young said that we could get data to the University of Washington in a matter of a couple of seconds, she was talking a language that I understood professionally and that you understood emotionally.

I feel so strongly about this kind of program. I do not know whether the panel knows, but I was in the computer and the data processing industry. I started a company called ADP, and since I have signed up with Government here, I look back fondly sometimes to those days. I know how important what you are talking about is.

I do want to say that I am pleased to participate in this, our third day of hearings on the NASA authorization for fiscal year 1985, and I welcome the opportunity to examine with the panel the administration's proposal to ground and downgrade the program for ACTS.

I have made no secret of my view that the administration's proposal on ACTS is ill advised. Our society and our economy have long since entered the information age. Mr. Fthenakis said it; over 50 percent of the people employed in our society are employed actually in information processing, one way or the other.

Communications satellites will play an increasingly significant role in the future in providing additional jobs to people who build and operate systems and enhancing productivity and improving communications for the people who use those systems.

American leadership has brought us this far. The question now is: Will we lead on? Competition from abroad is building. We see it in rising governmental investment in local industry, we see it as foreign firms penetrate subsectors of the industry, as was mentioned here earlier. We see it in protectionist trade policy. Japan has declared that NT&T [Nippon Telephone & Telegraph] simply will not purchase American satellites.

Senator GORTON. Japan will build its own.

Senator LAUTENBERG. They want their own domestic industry. And, of course, then they are going to try and sell it around the world.

The ACTS program will enable us to retain an edge by leaping over the state of the art. The program offers the opportunity to prove technologies that have been years in the making that are ripe for testing. We can prove technologies that will conserve spectrum space, enhance efficiency, expand the reach of satellite communications, and increase the variety and the speed and reliability of the service that satellites provide.

The administration proposes that we take on these challenges lying down. They have proposed a trimmed-back, ground-based program, and we cannot beat a competitive and technological challenge sitting down.

I am confident the hearing has already established that the proposal, the Hughes proposal on which the administration is placing a great deal of reliance, does not, in my view, justify pulling back. Proposals do not prepare technological research. And if we are going to build ACTS, we have to fly ACTS. That is the way we pushed the technology in this industry in the past, and that is what we must do in the future.

Foreign competition, as you folks have testified, is not going to stand still. We think our commitment should be to lead, as we always have.

I want to be certain about one thing here; that none of you or your organizations have direct financial interest in the ACTS program. I know that the residual benefits are there for all in your industries to share.

But are you subcontractors in any way in this program, any of you?

Dr. YOUNG. We would expect to be under contract to NASA to organize experiments on the program, Senator Lautenberg, as we have with the ATS-6 and CTS programs; that is, since we are nonprofit, basically a passthrough cost, but that is a role that we have played with the agency before, and we would expect to do so again

Even absent that role, however, our testimony would remain the same.

Senator LAUTENBERG. Any other comments?

Mr. Fthenakis.

Mr. FTHENAKIS. No, we are not participating.

Senator LAUTENBERG. You are not?

Mr. Gould, some of your members, I am sure, will be affected in terms of opportunity.

Mr. GOULD. Yes.

Senator LAUTENBERG. But it is not a specific that benefits your group especially differently than any other program of this size or magnitude.

Mr. GOULD. No; and it is difficult to take a stand on a particular issue that will be endorsed by all our members. Some of our members are employed at Hughes Aircraft Co., some are employed in the Department of Defense, some are employed in general industry. The views I'm expressing here on the desirability of the ACTS flight program are those of the research and development committee of the IEEE..

Senator LAUTENBERG. I could not get over the response to the flight test question that Senator Gorton asked, because to me it seemed so obvious; no matter what we do by way of ground testing or laboratory testing the fact is that until you are in the atmosphere, you really do not know how these things are going to work, and it is part of what I think is the proper experimental process that you have got to fly this thing.

I just want to run through a few statements here and just be certain that I did understand what you were saying.

You all seem to believe the ACTS program was well conceived, developed certainly over a long period of time, and is responsive to a national need to maintain leadership in satellite communications. Yes?

Mr. GOULD. Yes.

Senator LAUTENBERG. The ACTS program does not duplicate the Hughes program other than using the 20/30 GHz frequency range. Does it?

Dr. YOUNG. There are areas of overlap, but the significant technology that makes ACTS what it is is not the same. I have included in my testimony a couple of comparison charts, Senator, and I will let those stand for our reading of the situation.

Senator LAUTENBERG. OK.

One is more commercially oriented, designed to respond to market needs of the late 1980's. The other more an experimental system intended to be useful to U.S. industry in the 1990's and beyond. Is that correct?

[Panel nodding affirmatively.]

Senator LAUTENBERG. The Milstar program does not duplicate the technology proposed under ACTS, and therefore, is it fair to say that we can't expect much by way of technology transfer from the military system to the commercial?

Dr. YOUNG. That is our interpretation.

Senator LAUTENBERG. I guess we ought to get an audible nod for the record.

A ground test program for ACTS is really a break from NASA's historical role of doing flight tests of ACTS [Advanced Communications Technology Satellite]. Flight test programs, as I think we have all agreed, are critical for U.S. industry to deal with these new technologies.

Mr. FTHENAKIS. That is correct.

Senator LAUTENBERG. Flight tests are critical?

Dr. YOUNG. Yes.

Senator LAUTENBERG. What would the market and economic implications be to the United States, if you can summarize, of not

flying the ACTS system? What would our competitors be likely to do? Can anybody project that?

Mr. FTHENAKIS. I do not think I can project that in numbers, but I think the implications would be pretty serious. That is, I am sure before we are through, even in Government critical programs, we are going to start having foreign components on critical programs. And I indicated one—the TDRSS program. That will continue with an increasing pace.

Senator LAUTENBERG. Mr. Gould.

Mr. GOULD. If I can focus on another international implication—repeat it, rather.

We have been saying to the developing countries, there will be a place in space for you; do not worry. But these countries have been saying that they have got to have their names on slots in the orbit because there might not be anything left when they are ready to proceed. If we do not demonstrate our commitment to developing the technology that we say is the answer to this impending shortage, they will not have any confidence in relying on what we say. We will have to prove that we are committed to developing the technology—and then actually do it—so that this capacity increase will be realized.

Senator LAUTENBERG. This is significant to these lesser developed countries, the fact that the frequencies and the orbits are being absorbed by what is the proposed technology under the Hughes system or the systems that we are operating with now. Is that——

Mr. GOULD. We have been doing that for years. We started off with satellites spewing their power in all directions into space. We eventually concentrated that into beams pointing toward the Earth, covering the visible Earth; then to spot beams covering only a portion of the Earth. We have increased power; we have reused frequencies by cross-polarization, many of these advances by the way, pioneered in NASA-supported programs.

But the next generation of technology won't just come up out of the ground by itself. Those diamonds are deeper and deeper every year, and we have to dig for them. The NASA ACTS flight program is one way we would have uncovered or developed that technology.

Dr. YOUNG. Senator, it is difficult to quantify, as Mr. Fthenakis has said. There was a forecast by Western Union made in June of 1981 that the total market, worldwide for communications satellites and Earth stations would be on the order of $38 billion. Interestingly enough, by far the largest segment of that, roughly half, is North America, including the United States, Canada, and Mexico.

I think it is fair to say that in the latter part of that period, basically from 1990 to 2000, at least some of those satellites and Earth stations are going to be operating at the higher frequencies and with advanced technology. Therefore, if U.S. industry is not in the position to develop it, clearly we lose some portion of that $38 billion market.

The other thing which was interesting at the time we developed, or Western Union developed this chart, we found in the Economist of August of 1982 an analysis then of the export race for telecommunications equipment that was current as of 1981. And Japan was leading all other countries, including France and the United

States, West Germany, and everybody else, in terms of the total value of telecommunications equipment exported.

Now, clearly, that includes computers and television sets. But I think it gives us an understanding of the aggressiveness of some of the foreign governments. The United States, incidentally, in that chart, was third from the bottom.

Senator LAUTENBERG. Confirming what you have said, I have made mention here—and I think it is worthy of repeating, I guess—as I do of all the statements I make, Mr. Chairman—but the fact is that we have gone from a surplus on the export side in telecommunications with Japan of $200 million in 1 year, 1982, to a deficit of $200 million; the year following, $200 million again. The span was $400 million worth of change in the period of a single year.

And we know that the opportunities for all kinds of business in the future rest in the communications area, and again with all due respect, a very aggressive, very skillful competitor—I saw it when I was in the business world and we were doing business overseas, how much hostility there was to American technology because everybody wants to reserve that space—to use the pun—for themselves, for their own industry's future. And it is now an aggressive commercial war out there, and we have to take advantage of it and not run the risk that we will be following instead of leading.

Dr. Young, you addressed the issue of whether ACTS gives an unfair advantage for participants. That relates to testimony Mr. Beggs made last week when he was here. He argued that ACTS would unfairly compete with the Hughes proposal; that ACTS would unfairly eclipse it.

What do you think of that? Isn't progress always going to put pressure on older technologies, to use that reference? If ACTS is successful, isn't it going to have an impact, competitive impact, if you will, on the whole industry?

Is that a reason to hold back? Do you think it would, if we held back, that our competitors from abroad will hold back also?

Dr. YOUNG. Senator, I read that comment. It was republished in some of the trade press. And I frankly did not understand it. For one thing, the ACTS program, as we all know, is an experimental program with technology transfer available to all of U.S. industry.

Second, as this group and others have pointed out, what Hughes is proposing is a commercially viable system for the last part of this decade. Presumably, Hughes will have just as much of an opportunity to adapt and adopt the technology advacements available through ACTS for their next generation of satellites as will American Satellite or Western Union or RCA or anybody else.

So, far from being competitive, it is an experimental, noncommercial, 2-year-lived satellite, which demonstrates advanced technology. That is of benefit to everyone in U.S. industry, Hughes included.

Now, if the Government were flying a satellite that took service opportunities, that is customers away from a commercial supplier, clearly that would be inappropriate. But that is simply not the case here. So, with all due respect, sir, I found some difficulty understanding the comment.

Mr. FTHENAKIS. May I add something?

Senator GORTON. Please.

Mr. FTHENAKIS. From commercial experience, I would say, probably it would have the opposite result. It would be enhancing. That is, if I am proposing a system on a certain technological basis, which is today's technology, and somebody else funds my second step on that system, that tends to enhance my first step.

So I would say that probably would have the opposite effect.

Senator LAUTENBERG. OK.

You made reference already in Senator Gorton's question about the availability of communications links with the rural areas. This is not accomplished, I assume, in the Hughes proposal. The Hughes system specifically would be targeted as a result of the technology to the larger urban or commercial centers.

Dr. YOUNG. That is correct; yes.

Senator LAUTENBERG. I am confirming that. Because there is some concern on this committee about the fact that the rural areas of our country are often left out of advancing technology, and this is one way to insure that—not insure, but at least protect the possibility that these people will be able to communicate, these companies will be able.

Yes, Mr. Gould.

Mr. GOULD. Sir, in future commercial developments, technology that is being developed in ACTS will permit service to 3-meter antennas, which means that many more small communities can justify the cost of an Earth station, and thereafter, the capacity of a commercial system using these techniques can be switched instantaneously to wherever the demand is. As it builds up in one place throughout a day, throughout a week, throughout the years, the capacity can be redirected.

Senator LAUTENBERG. It has been encouraging to see the signs that the Congress is not going to accept the proposal to trim back and ground the ACTS program. But I am concerned about a couple of things.

First, a half a loaf. The administration is asking for $5 million in this next fiscal year 1985. The funding is supposed to be $90 million to get all the subcontractors going.

What if we in the Congress decide to split the difference, fund the program somewhere in the middle, stretching the time schedule? How does that strike any of you?

Dr. YOUNG. Senator, I will start on that.

In my written statement I make note of the fact that that will probably simply have the effect of delaying the program by half a year, which will not damage it so critically that it cannot go forward. It is just that it is a 6-month delay.

Obviously, again, we are up against certain time binds with potential foreign competition and with the willingness of the team, of course, and with the experimentors to sustain that delay. But it would seem to me that would be the most immediate effect.

Quite frankly, sir, the greater fear I have is that we will be sitting here again, having the same discussion next year and the year after. And if I may say this, I think whatever level of support Congress wants to give to the program, it is equally important if Congress feels that it wants to do this, to let the agency know that they do support the continuation of the program. It is a great

waste of the taxpayers' money to have to reargue these questions every year, as pleasant as it is to have the intellectual exchange.

Senator LAUNTENBERG. And again, it has been said so many times that our competitors from abroad are not going to wait and let us catch up or preserve the edge that we have.

How well are foreign firms doing in the satellite-related markets? The Japanese may not be outselling us when it comes to the satellites themselves, not yet anyway, but how are they doing with things like Earth stations?

My understanding is that Nippon Electric is doing quite well.

Mr. FTHENAKIS. That is correct. It is the No. 1 supplier of Earth stations in the world.

Senator LAUTENBERG. The No. 1?

Mr. FTHENAKIS. No. 2 is a French company, Thompson CSF.

Senator LAUTENBERG. ACTS would give U.S. industry, therefore, a second chance? New and different Earth stations would be needed to accommodate this technology. We would have the experience working with—experimenting with ACTS, and we would, I think, be in the best position to exploit that technology.

Would you agree with that? New opportunity there?

Mr. GOULD. Yes, sir. The ACTS program will result in commercial system with thousands of Earth stations, and we will not be as well-equipped to compete to supply our own markets, as well as any foreign markets that develop for that large number of Earth stations if we have not been involved in the development of the technology, the baseband processor and the ground control that uses that technology.

Senator LAUTENBERG. Thank you very much, Mr. Chairman. Thank you, panel. That was very interesting. I assume that you noted that we might have agreed on a thing or two.

Senator GORTON. I should like to thank the panel as well for its enlightenment and its great help to us.

We will now proceed to panel 2 on space science and applications with Mr. Willis Shapley of the Space Applications Board, Dr. Thomas Donahue of the Space Science Board, and Dr. Lennard Fisk of the Space Science Working Group, if they will come forward.

Your entire written statements and the appendixes thereto will be included in the record as if read in full. We will have a 10-minute time limit on oral presentations and would be happy with less, if you can do so.

We will start with Mr. Shapley.

STATEMENTS OF WILLIS H. SHAPLEY, NATIONAL ACADEMY OF SCIENCES, SPACE APPLICATIONS BOARD; DR. THOMAS DONAHUE, NATIONAL ACADEMY OF SCIENCES, CHAIRMAN, SPACE SCIENCE BOARD; AND DR. LENNARD A. FISK, JR., SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES

Mr. SHAPLEY. Mr. Chairman, on behalf of the Space Applications Board of the National Research Council, I would like to thank you for the invitation to participate in your hearing today to give you

the Space Applications Board's current thinking on the NASA space applications program.

My name is Willis Shapley. I have been a member of the Space Applications Board since 1978, and am appearing in place of George Harter, our chairman, who is unable to be here today. I am now a consultant to the American Association for the Advancement of Science. From 1965 to 1975 I was the Associate Deputy Administrator at NASA.

The Space Applications Board was formed by the National Academy of Engineering back in 1973 to give independent advice to NASA and other agencies, help formulate the space applications programs, and to assist in broadening the understanding of industry, universities, and government and the public in the practical applications of space technology.

Getting to the 1985 budget, I should say that the Board was briefed on the NASA and NOAA space applications programs in their 1985 budgets at its meeting on February 7 and 8, 1984. The Board has not reviewed the budgets in detail, but it has followed the space applications programs over a period of years and discussed many of the principal issues that are still alive in the 1985 budget.

I will do my best, then, to give you the consensus of the Board as accurately as I can.

In the area of communications you have just had exhaustive testimony, so I will abbreviate my statement on that subject and you can read the full statement in the record. You will find it bears a certain resemblance to the statements you have just been hearing.

In summary, the Board is very concerned with what appears to it to be an unwise decision to terminate the flight test phase of the ACTS, advanced communication technology satellite program.

I should mention that the Space Applications Board takes a paternal interest in this program, since the program was started largely as a consequence of some recommendations that the Board made in a report that was published in 1977, which the general parameters of the program have followed from that time.

I should also point out and get in the record that the ACTS program has been actively supported in Congress. Actually, it was started at least a year sooner than it might otherwise have been by actions originating in Congress.

The third point I would like to emphase on it is that ACTS is, as you have heard, a broad technological program; it is not just a program to use the 20/30 GHz band, and it does require flight testing to achieve its objectives.

The fourth point I would like to make is that it is a joint Government/industry program. In recent years, both the administration and Congress have been encouraging NASA and other agencies to find ways of involving industry more directly in their programs, so that the full expense is not borne by the Government.

Now, the ACTS program, in my opinion, was an outstanding experimental effort at such an arrangement. It would certainly be a pity if we do not see what the results of that experiment are.

We believe that the evidence of this country's need for continuing growth in space communications capacity is clear. We also believe that NASA, working with industry, is the appropriate agency

to sponsor high-risk research and development activities, including flight testing that will result in improved services to users and to a strengthening of U.S. industry. We hope that the decision to drop the flight test phase will be reconsidered and that NASA will be enabled to move toward an early implementation of the ACTS flight program.

Now, let me turn to materials processing. The subcommittee may recall that in this case also, the Space Applications Board had a committee some years ago, under Dr. William Slichter of the Bell Laboratories, which issued a report that recommended a program of ground-based research and development in materials processing, supplemented by occasional flight testing of promising successes.

NASA has followed this program, and there are cooperative research activities in some 30 to 40 universities and other research agencies, and the work is going ahead. Some experiments have already been done, and more are planned, on space shuttle flights.

We believe this program is proceeding in the right direction, but are worried that it is a bit thin and that there may not be enough stability in the ground-based cooperative research program, and we would also like to see provision made for more flight research opportunities if it is possible to do so.

In the remote sensing area, we have problems. In recent months the Space Applications Board has been studying the field of civil remote sensing in space, where, in our opinion, there are serious problems. The Board has two activities underway in this field. One is addressed primarily to the requirements of present and prospective uses of remote sensing information. The Board's standing committee on practical applications of remote sensing from space is attempting to develop a future strategy for the remote sensing field.

This committee is made up primarily of users and processors of remote sensing data. Their views as to the needs for and the uses of such data will be the central element of the strategy we hope and intend to develop. The committee has planned a workshop for July of this year and anticipates issuing a report by late 1984 or early 1985.

In the meantime, the Board itself, with the assistance of the committee, is taking another look at present and past institutional arrangements, both public and private, in the civil remote sensing field. As the time approaches when decisions will have to be made on the responses to the requests for proposals for transfer to the private sector of the Landsat systems and on the related legislation, we want to try to develop a clear view on the basic question, "Who should do what in the future?"

This is indeed a difficult question, as attested by the travails in the executive branch and Congress of the past several years.

In our preliminary view, it does not make sense to dump the entire responsibility into the lap of industry and say "sink or swim." There are Government needs and public benefits that should not be lost. It also appears to be in the public interest for NASA to have a long-term role as a developer of new technology for remote sensing.

Whether or not the Board will recommend that this role should include fight demonstration and operational trials remains to be determined. The Board hopes to be in a better position to comment

on these matters by late spring or early summer, and we will be pleased to share our views with you at that time.

With respect to the 1985 budget, it appears to us that uncertainties on the outcome of the Landsat privatization effort may have resulted in undue curtailment of NASA R&D activities necessary to maintain long-term U.S. leadership in remote sensing.

In what NASA now calls the solid Earth observations area, for example, we feel the provision made for future instrument development is minimal; that not enough support appears to be provided for research and analysis work on the practical uses that can be made of the thematic mapper data now available, more of which will be coming available now that Landstat V is in orbit; and, finally, that the SIR, synthetic apperture radar series of land and sea radar observations from the shuttle deserves stronger support.

These are developments, experiments, and research that we feel are vital to continue at a somewhat better pace than proposed in the budget in the remote sensing field.

In the environmental observations field, we are pleased that the upper atmosphere research satellite is going forward. We continue to be concerned, however, that there appears to be no provision in the either the NASA or the NOAA budget for the development of new operational-type flight instruments with advanced sensors for incorporation as they become available into NOAA's operational meterological satellites.

Another aspect of this problem appears to be the lack of adequate provision on either the NASA or the NOAA side of capacity on currently planned satellites for flight testing new and advanced instruments in the research and development stages.

It appears that an agreement or a decision is needed on the respective responsibilities of NASA and NOAA in these matters, backed up by dollars in the appropriate budget. Unless this problem is dealt with promptly, our operational weather satellites will be technologically obsolete in a few years, and we will deny ourselves the benefits from advancing sensor technology that could easily be ours.

These and my other points on remote sensing are not trivial. If we are concerned with our Nation's future standing in remote sensing, each of them should be given careful consideration.

Thank you, Mr. Chairman.

[The statement follows:]

STATEMENT OF WILLIS H. SHAPLEY, SPACE APPLICATIONS BOARD, NATIONAL RESEARCH COUNCIL

Mr. Chairman and Members of the Subcommittee, on behalf of the Space Applications Board of the National Research Council, I would like to thank you for the invitation to participate in this hearing. My purpose is to present, as you requested, the current thinking of the Board on the NASA space applications program.

My name is Willis Shapley. I have been a member of the Space Applications Board since 1978, and am appearing in place of George Harter, the Chairman of the Board, who is unable to be here today. I am now a consultant to the American Association for the Advancement of Science and other agencies. From 1965 to 1975 I was the Associate Deputy Administrator of NASA.

The Space Applications Board was formed by the National Academy of Engineering in 1973, and is now a part of the National Research Council, the operating organization of the National Academies of Sciences and Engineering. The Board's functions are to help formulate the nation's program for practical applications of space

systems, to give independent advice to NASA and other agencies, and to assist in broadening the understanding of industry, universities, government, and the public of practical applications of space technology.

Mr. Chairman, your letter of February 3, 1984 asked that we give our assessment of NASA's budget and planning for its space applications programs and any recommendations we might have as to program content and the level of funding needed to support these programs.

The Board was briefed on the NASA and NOAA space applications programs in their fiscal year 1985 budgets at its meeting on February 7-8, 1984. While the Board has not reviewed the fiscal year 1985 budgets in detail, it has followed closely and discusses most of the principal civil space applications programs over a period of years. I believe, therefore, that I can convey accurately to you the Board's views on the main issues as we see them.

I will address in turn, the areas of communications, materials processing in space, and remote sensing, including both the solid earth observations and environmental observations programs.

COMMUNICATIONS

In the communications area our main concern is with what appears to us to be an unwise decision to terminate the flight test phase of the Advanced Communication Technology Satellite (ACTS) program.

The Space Applications board has been a proponent of the Advanced Communications Technology Satellite program since before its inception. In 1975, NASA asked and the Board agreed to study the question "Should federal research and development on satellite communications be resumed and, if so, what is the proper federal role in this field?" A committee on satellite communications was formed under the SAB, and was chaired by Wilbur B. Davenport of the Massachusetts Institute of Technology. The committee's report, entitled "Federal Research and Development for Satellite Communications" recommended that NASA implement an experimental satellite communications technology flight program in concert with the communications industry.

NASA responded by planning and initiating an advanced communication technology satellite that incorporates many pioneering technologies: use of the twenty and thirty GHz frequency bands; multiple-scanning, spot-beam antennae with on-board switching; time-division multiple access; and baseband processing in the satellite. These advanced techniques can open the way toward a greatly expanded U.S. telecommunications capability in the decade of the 1990s. It would be a tragic mistake to miss this opportunity and to yield U.S. leadership in satellite communications to other nations.

We believe it is an important part of NASA's role to ensure that there will be sufficient capacity so the country's space communications needs can be served. The only way to accomplish this goal is to develop and demonstrate improved technology. In the past several years, some of the country's best university scientists and communications and aerospace engineers have worked with NASA to delineate a program that will provide for conservation of the electromagnetic spectrum by means of novel and improved processing and transmission techniques. This program was previously referred to as the "30/20 GHz" program. However, the emphasis should be less on the frequencies (although it is important to open them up to commercial exploitation) and more on the technology that is being developed. At this stage, the program appears ready to enter an intensive period of test and development that must culminate in flight testing of the relevent technology if it is to be accepted for use in commercial systems.

We believe that the evidence of this country's need for continued growth of space communications capacity is clear. We also believe that NASA is the appropriate agency to sponsor high-risk research and development activities, including flight testing that will result in improved services to users and the strengthening of U.S. industry. We hope that the decision to drop the flight test phase will be reconsidered and that NASA will be enabled to move toward early implementation of the ACTS flight program.

MATERIALS PROCESSING

With respect to materials processing in space, the subcommittee may recall that a committee of our Board under the chairmanship or William P. Slichter of Bell Laboratories, issued a report in 1978 that recommended a program of ground-based research and development, supplemented by occasional flight testing of promising processes. NASA, in following this program, has established cooperative research ac-

tivities with some 30 to 40 universities and research agencies and has developed a commendable background of research in materials sciences and technology. In addition, NASA has begun to use the shuttle as a vehicle for pilot testing of materials processing in space.

We believe this program is proceeding in the right direction, but would like to see more long-term stability in the ground-based cooperative research program and more flight-research opportunities made available on space shuttle flights.

REMOTE SENSING

In recent months, the Space Applications Board has been studying the field of remote sensing in space where, in our opinion, there are serious problems. We have two activities underway in this field.

One is addressed primarily to the requirements and prospects of present and prospective uses of remote sensing information. The Board's standing Committee on Practical Applications of Remote Sensing from Space is attempting to develop a future strategy for the remote sensing field. The Committee is made up primarily of users and processors of remote sensing data and their views as to the needs for and the uses of such data will be the central element of the strategy we intend to develop. The Committee has planned a workshop for July of this year and anticipates issuing a report by late 1984 or early 1985.

In the meantime, the Board itself, with the assistance of the Committee, is taking another look at present and past institutional arrangements (both public and private) in the remote sensing field. As the time approaches when decisions will have to be made on the response to the Request for proposals (RFP) for privatization of the LANDSAT systems and on the related legislation, we want to try to develop a clear view on the basic question, "Who should do what in the future?" This is indeed a difficult question, as attested by the travails in the Executive Branch and Congress of the past several years.

In our preliminary view, it does not make sense to dump the entire responsibility into the lap of industry and say "sink or swim." There are government needs and public benefits that should not be lost. It also appears to be in the public interest for NASA to have a long-term role as a developer of new technology for remote sensing. Whether or not the Board will recommend that this role should include flight demonstration and operational trials remains to be determined. The Board hopes to be in a better position to comment on these matters by late spring or early summer; we will be pleased to share our views with you at that time.

With respect to the fiscal year 1985 budget, it appears that uncertainties on the outcome of the LANDSAT privatization effort may have resulted in undue curtailment of NASA R&D activities necessary to maintain long-term U.S. leadership in remote sensing.

In the *Solid Earth Observations* area, for example, we feel the provision made for future instrument development is minimal, that not enough support appears to be provided for research and analysis work on the practical uses that can be made of the Thematic Mapper (TM) data now available, and that the SIR series of land and sea radar observations from the shuttle deserves stronger support.

In the *Environmental Observations* field we are pleased that the upper atmosphere research satellite (UARS) is going forward. We continue to be concerned, however, that there appears to be no provision in either the NASA or the NOAA budget for the development of new operational-type flight instruments, with advanced sensors, for incorporation, as they become available, into NOAA's operational meteorological satellites. Another aspect of this problem appears to be the lack of adequate provision, on either the NASA or the NOAA side, of capacity on curently planned satellites for flight-testing new and advanced instruments in the research and development stages. It appears that an agreement or decision is needed on the respective responsibilities of NASA and NOAA in these matters, backed up by dollars in the appropriate budgets. Unless this problem is dealth with promptly, our operational weather satellites will be technologically obsolete in few years, and we will deny ourselves the benefits from advancing sensor technology that could easily be ours.

These and my other points on remote sensing are not trivial. If one is concerned, as we should be, with our nation's future standing in remote sensing, each of these points should be given careful consideration and provided for in the NASA, or where appropriate, the NOAA budget.

Mr. Chairman, this concludes my statement.

QUESTIONS OF SENATOR GORTON AND THE ANSWERS THERETO

Question. NASA's fiscal year 1985 budget request includes a new start for a joint NASA/DOD project to develop the Navy Remote Ocean Sensing System (N-ROSS) Scatterometer. Could you comment on the significance of this new ocean remote sensing capability?

Answer. The scatterometer instrument development included in NASA's fiscal year 1985 budget request and intended for the Navy Remote Sensing System will be used to determine the relationship between sea-state and surface winds. On the basis of our current information, we believe that such measurements will be useful for both civil and military applications. Surface winds are one of the forces that drive ocean currents. Moreover, a knowledge of surface winds is vital to the safety and efficiency of military and civil sea-transport.

Question. NASA has just signed a Memorandum of Understanding with a private firm to explore the feasibility of developing and demonstrating a specialized commercial orbiting structure called the Industrial Space Facility. Even though the Facility is planned to be in operation several years before the proposed U.S. space station, it will be designed to be compatible with the proposed space station system. Could you comment on the significance of such a facility on space manufacturing processes, and what are the unique considerations of a project such as this?

Answer. On the basis of information we have, the Memorandum of Understanding signed recently between NASA and a private company is intended to provide for the development by the company of a large pressurized spacecraft, suitable for attachment to the space shuttle, at first, and later to the space station. In use with the shuttle, it would be left in orbit and revisited regularly by the shuttle. The spacecraft would receive life support services from the shuttle but would have its own power source. This undertaking could provide a suitable vehicle for materials processing in space several years before the space station would be available. It could provide long durations for materials processing, occasional manned supervision, and manned access for supplying materials to be processed and retrieving the materials when processing is complete.

Senator GORTON. Thank you.

Dr. Donahue.

Dr. DONAHUE. Senator Gorton and members of the subcommittee, it is indeed a pleasure for me to appear here today to discuss the scientific issues in the space program, particularly as they are raised in the fiscal year 1985 budget request of NASA.

The overriding issue in fiscal year 1985 is the request for a start on the space station and the impact that initiative will have on space science. This subcommittee held hearings on this matter last fall, and I had the privilege of testifying at that time. I refer you to that testimony and shall not repeat it in detail here.

If the Congress agrees with the administration and authorizes it to proceed with the construction of this facility, the Board will cooperate in every way in its power to maximize the usefulness of the space station to science. We have expressed this determination to Mr. Beggs, and I am pleased with the level of mutual understanding that seems to exist between us on this issue.

But, of course, as I also said in my testimony, we are concerned lest the bad experience space science has had in coexisting with the space shuttle development program be repeated with the space station. A large number of excellent potential space science missions have already been developed in concept, that are responsive to the strategies of the Board and its committees, that do not need the space station for their implementation. If the Nation wishes to continue to be in the forefront of science and space, then means will have to be found to launch such science missions at a reasonable rate with existing spacecraft while the space station is being prepared.

If further delays in starting and orbiting high priority missions while we wait for the space station should be added to those already imposed while we waited for the shuttle in its upper stages, space science will be left in atrophy.

I hope that if a cap should be placed on the NASA budget during the years ahead, it will not be done in such a way as to prevent space science from expanding to the level of activity implied by the establishment of a space station. Possibly the greatest budgetary uncertainty during the next few years is in the level of reimbursables in space transportation. I hope that space science will be protected from unforseen fluctuations in these reimbursables, for they could be quite large.

As I also said in my earlier testimony, care must be taken as the space station system is being defined and after it is in place, to accommodate science missions that do not lend themselves readily to close support by the space station because of the orbit needed or other requirements.

We are pleased with the willingness expressed by NASA to make usefulness to science a major factor in designing the space station. The formation of the Space Station Task Force of the Space and Earth Science Advisory Committee is a positive step. So also would be a decision to ask the Goddard Space Flight Center and the Jet Propulsion Laboratories as representatives of the space science component of NASA, to play an integral, high-level role in planning the space stations.

It would also seem to be wise for NASA to establish some administrative apparatus at headquarters to represent science at a high level in the space station planning and guard against the kind of deterioration of the science mission of NASA that occurred during the decade of shuttle development.

Turning now to the specifics of the fiscal year 1985 requests in space science, I am pleased to see three proposed new starts there—the upper atmosphere research satellite, the Mars geoscience climatology orbiter and, by my way of counting, the scatterometer. In most respects this is an encouraging budget for space science. It has been a long time since three new starts were requested. We have waited a long time to see the UARS get underway. It is indeed time that we obtain the global inventory of trace gases in the upper atmosphere simultaneously with measurements of wind and temperature. These are needed to understand the impact of life processes on the surface and in the waters of the Earth on the upper atmosphere. Flying the scatterometer on the NOSS mission will provide us with some of the data we shall need to understand the global circulation of the ocean. I hope that NASA follows through promptly in the coming years to complete the job by coming forward with proposals to start Topex, the ocean topography experiment, and GRM, the geodynamics research mission.

The appearance of the request for the Mars geoscience climatology orbiter is a welcome token of NASA's responsiveness to the Solar System Exploration Committee report. Unfortunately, I have to note with regret that the administration has failed to respond to a key element in the recommendations of the SSEC; that this mis-

sion be the first in a level of effort series called the planetary observers.

Stability and affordability were what the SSEC was trying to bring to the base program in planetary studies. In doing so, it was being responsive to advice from the Congress and the science adviser. There is a risk involved in transforming the way we do planetary science from reliance on elaborate, comprehensive missions to smaller, more affordable ones. Because of the limited scope of each mission, it is essential that each one be a part of a well-planned continuing sequence.

Commitment to level of effort funding is necessary to provide stability, flexibility, and economy in this new way of doing business. I thought that the SSEC had done a responsible and careful job. It is a pity that its recommendations are not being followed.

Although these remarks have been directed toward the planetary observer portion of the planetary exploration core program, it is important to keep in mind that they are only a part of that program. There are also missions that need the new Mariner Mark II spacecraft being defined by the Jet Propulsion Laboratory, and there is essential R&A and mission operations and data analysis infrastructure. All are components of this minimal program defined by the SSEC. Furthermore, a core program implies the existence of more elaborate augmented enterprises that will be needed from time to time.

In astronomy and astrophysics, I fear that we are seeing the effects of the Hubble space telescope overruns on other programs. The proposed funding for the advanced X-ray astronomy facility experiments is welcome, but probably not adequate. There is not money requested to start work in defining the space infrared telescope facility and the solar optical telescope is still delayed.

The delay in the ST program was caused predominantly by management shortcomings, and not be scientific or even technological impediments. Unfortunately, the penalty for the delays is being paid in part by the science programs of the future.

On the other hand, those technical problems that did confront the space telescope last year seem to be behind us. There seem to be no "show stoppers" ahead for the optical telescope assembly. The fine guidance system works, the mirror can be cleaned, the latches have been fixed, and it looks as though the OTA will emerge from the doors of Perkin Elmer in time to meet the revised schedule.

Scientists close to the project are very pleased with the technical excellence that is being realized by this splendid instrument. If no serious problems develop during integration and verification at Lockheed, the telescope should be ready for launch at the revised date—if no serious problems develop.

Obviously, however, there is no guarantee that some delays will not occur, but NASA management seems quite firm about meeting the schedule and holding to the present budget. NASA must guard, however, against allowing this preoccupation with management problems to cause it to forget that the purpose of the mission, after all, is to do science. It is most important that the Space Telescope Science Institute be ready to support the operation of the facility after it begins to operate.

The space telescope and the Science Institute will profoundly change the future course of American astronomy in a way not fully perceived, I think, by the astronomical community.

Senator GORTON. Doctor, you have just about 1 minute left, so if you can summarize the rest of your testimony, it is all going to be included in the record.

Dr. DONAHUE. Very well.

I think that what I want to emphasize in the rest of my testimony is particularly to ask that the erosion in the research and analysis infrastructure of the budget not be permitted to continue. The Congress has been very effective in restoring shortfalls in that budget in the past, and I hope that you will continue to cooperate with us in this regard in the future.

[The statement follows:]

STATEMENT OF DR. THOMAS M. DONAHUE, CHAIRMAN, SPACE SCIENCE BOARD, NATIONAL RESEARCH COUNCIL

It is a pleasure for me to appear here today to discuss scientific issues in the space program, particularly as they are raised in the fiscal year 1985 budget request of NASA.

I am sure you know, but for the record I shall repeat, that I represent the Space Science Board (SSB) of the National Research Council. The Board has been charged by the Council to monitor the health of space science. Our responsibility is expressed in developing the strategies for space research developed by our committees for the guidance of NASA in mission selection, in assessing the responsiveness to those strategies of the science content of those missions, in gauging the quality of long-range planning, and in judging the adequacy of the supporting elements of the U.S. space science programs at universities, centers, and institutes.

Of course the overriding issue in fiscal year 1985 is the request for a start on the Space Station and the impact that initiative will have on space science. This subcommittee held hearings on this matter last fall, and I had the privilege of testifying at that time. I refer you to that testimony and shall not repeat it in detail. If the Congress agrees with the Administration and authorizes it to proceed with the construction of this facility, the Board will cooperate in every way in its power to maximize the usefulness of the Space Station to science. We have expressed this determination to Mr. Beggs, and I am pleased with the level of mutual understanding that seems to exist between us on this issue. But, of course, as I also said in my testimony, we are concerned lest the bad experience space science has had in coexisting with the Space Shuttle development program be repeated with the Space Station. A large number of excellent potential space science missions have already been developed in concept that are responsive to the strategies of the Board and its Committees that do not need the Space Station for their implementation. If the nation wishes to continue to be in the forefront of science in space, then means will have to be found to launch such science missions at a reasonable rate with existing spacecraft while the space station is being prepared. If further delays in starting and orbiting high priority missions while we wait for the Space Station should be added to those already imposed while we waited for the Shuttle and its upper stages, space science will be left in atrophy. I hope that if a cap should be placed on the NASA budget during the years ahead it will not be done in such a way as to prevent space science from expanding to the level of activity implied by the establishment of the Space Station. Possibly the greatest budgetary uncertainty during the next few years is in the level of reimbursables in space transportation. I hope that space science will be protected from such fluctuations, for they could be quite large.

As I also said in my earlier testimony, care must be taken as the Space Station system is being defined and after it is in place to accommodate science missions that do not lend themselves readily to close support by the space station because of the orbit needed for other requirements. We are pleased with the willingness expressed by NASA to make usefulness to science a major factor in designing the Space Station. The formation of a space station task force of the Space and Earth Science Advisory Committee is a positive step. So also would be a decision to ask the Goddard Space Flight Center and the Jet Propulsion Laboratory, as representatives of the space science component of NASA, to play an integral, high level role in planning the Space Station. It would also seem to be wise for NASA to establish some

administrative apparatus at Headquarters to represent science at a high level in the Space Station planning and guard against the kind of deterioration of the science mission of NASA that occurred during the decade of Shuttle development.

Turning now to the specifics of the fiscal year 1985 requests in space science, I am pleased to see three proposed new starts there, the Upper Atmosphere Research Satellite (UARS), the Mars Geoscience Climatology Orbiter (MGCO), and, by my way of counting, the Scatterometer. In most respects this is an encouraging budget for space science. A lot of people within NASA and elsewhere in the Administration including, in particular, Dr. Keyworth and his staff deserve commendation for their success in producing real growth in NASA's space science program during the past couple of years. The strong support of this committee and other relevant elements of Congress has also been essential in supporting these initiatives as well as correcting deficiencies in the budget requests when they have existed. It has been a long while since three new starts were requested. We have waited a long time to see the UARS get underway. It is indeed time that we obtain a global inventory of trace gases in the upper atmosphere simultaneously with measurements of wind and temperature. These are needed to understand the impact of life processes on the surface and in the waters of the Earth on the upper atmosphere. Flying a Scatterometer on the NOSS mission will provide us with some of the data we shall need to understand the global circulation of the ocean. I hope that NASA follows through promptly in the coming years to complete the job by coming forward with proposals to start TOPEX, the ocean topography experiment and GRM, the Geodynamics Research Mission.

The appearance of the request for the Mars Geoscience Climatology Orbiter (MGCO) is a welcome token of NASA's responsiveness to the Solar System Exploration (SSEC) Report. Unfortunately, I have to note with regret that the Administration has failed to respond to a key element in the recommendations of the SSEC—that this mission be the first in a level of effort series called the Planetary Observers. Stability and affordability were what the SSEC was trying to bring to the base program in planetary studies. In doing so, it was being responsive to advice from members of Congress and the Science Advisor. There is risk involved in transforming the way we do planetary space science from reliance on elaborate, comprehensive missions to smaller, more affordable ones. Because of the limited scope of each mission, it is essential that each one be a part of a well-planned continuing sequence. Commitment to level-of-effort funding is necessary to provide stability, flexibility, and economy in this new way of doing business. I thought that the SSEC had done a responsible and careful job. It is a pity that its recommendations are not being followed. Although these remarks have been directed toward the Planetary Observer portion of the Planetary Exploration core program, it is important to keep in mind that they are only a part of that program. There are also missions that need the new Mariner Mark II spacecraft being defined by the Jet Propulsion Laboratory. And there is the essential R&A and mission operations and data analysis (MO&DA) infrastructure. All are components of this minimal program defined by SSEC. Furthermore, a core program implies the existence of more elaborate augmented enterprises that will be needed from time to time.

In astronomy and astrophysics I fear that we are seeing the effects of the Hubble Space Telescope (ST) overruns on other programs. The proposed funding for the Advanced X-ray Astronomy Facility (AXAF) experiments is welcome but probably not adequate. There is not money requested to start work in defining the Space Infra-Red Telescope Facility (SIRTF), and the Solar Optical Telescope (SOT) is still delayed. The delay in the ST program was caused predominantly by management shortcomings and not by scientific or even technological impediments. Unfortunately the penalty for the delays is being paid in part by the science programs of the future.

On the other hand, those technical problems that did confront the Space Telescope last year seem to be behind us. There seem to be no "show stoppers" ahead of the Optical Telescope Assembly (OTA). The Fine Guidance System works, the mirror can be cleaned, the latches have been fixed, and it still looks as though the OTA will emerge from Perkin Elmer in time to meet the revised schedule. Scientists close to the project are very pleased with the technical excellence being realized by this splendid instrument. If no serious problems develop during integration and verification at Lockheed, the Telescope should be ready for launch at the revised date. Obviously, however, there is no guarantee that some delays won't occur, but NASA management seems quite firm about meeting the schedule and holding to the present budget. NASA must guard, however, against allowing this preoccupation with management problems to cause it to forget that the purpose of the mission after all is to do science. It is most important that the Space Telescope Science Insti-

tute (STScI) be ready to support the operation of the facility after it begins to operate. I have great confidence in the competence and dedication of the Institute staff to do so if NASA provides them with the means in a timely fashion. When this great and costly instrument becomes ready, we should be in a position to exploit its capabilities from the very beginning. I hope also that plans are being developed for a program of preventive maintenance of the telescope after it becomes operational. In that way we will be able to prevent problems from developing that might take months or years to fix because of a lack of such a program. Furthermore, the practical experience gained in servicing the instrument periodically ought to prove very useful in case an emergency should develop.

The ST and the STScI will profoundly change the future course of American astronomy in a way not fully perceived by the astronomical community. With the establishment of a permanent observatory in space, space astronomy will achieve a level of maturity that will require more effective coordination between the space-based and ground-based organizations. Other observatories, such as the Gamma Ray Observatory (GRO), AXAF, and SIRTF, will follow. The institutional and fiscal implications of establishing these observatories and their attendant operational, support, and maintenance apparatus need to be examined and understood. It follows that there may be a need for an advisory structure that can communicate to all agencies concerned with astronomy as space activities become a larger and larger fraction of the total effort. The definition of this structure will require careful study by the various agencies, the National Research Council, and the Congress.

Last year when I appeared here, I commented on the sensitivity NASA was showing toward the problem of the poor health of University space science research groups. As a token of that sensitivity a Committee on NASA-University Relations was formed, chaired jointly by the Chief Scientist of NASA, Dr. Frank McDonald, and myself and consisting of representatives of the university community including members of the SSB and NASA. This committee recommended several emergency measures to NASA management in order to provide immediate succor to these university groups. Two of these recommendations have been adopted. They are for the establishment of NASA Graduate Student Traineeships and enhancement of data analysis funding at universities for science missions now existing or already finished. A third recommendation was for an 11 million dollar annual commitment for laboratory equipment needed to end the state of obsolescence of that equipment in many university research laboratories. This state has developed over the years because of the erosion that has taken place in supporting research and technology (now research and analysis, or R&A funding). A serious state has been allowed to develop in our university laboratories. Unfortunately, the budget request does not contain a line for funds needed to respond to the third recommendation.

Erosion of research and analysis funding would have been much more serious than it has been if the Congress had not intervened to increase funding when the Administration came forward with inadequate requests. Again this year the R&A requests fall short of the levels established by Congress last year. This is perplexing in view of the increased level of science activity implied by the new starts. Such an increase needs an enhancement of R&A support, not a decrease. The most serious question I must raise concerning this budget request is whether the provision of R&A, MO&DA, and Advanced Technology Development (ATD) infrastructure in it is nearly adequate to support the level of mission activity implied by the present request for new starts and realistic plans for the future.

The increases requested for Shuttle payload development, for the suborbital program, and for Explorers are laudable, especially if they reflect a preoccupation with increasing the rate at which flight opportunities will become available for small, university-sized payloads. A question, however, is whether the plans for using these funds provides for carrying through on the experience with Spacelab I. It is very important that we exploit our experience with the Space Shuttle to develop an adequate mix of Shuttle payloads from large facilities to small PI Class experiments.

One area of space research that traditionally has been one of the strongest in the space program is that of solar and space plasma physics, including solar-terrestrial research. During the past few years this field has suffered from a series of management reorganizations at NASA that left the disciplines less than adequately represented. Their science programs seem to have suffered accordingly. This year there are several welcome harbingers of change. One is the UARS initiative. Another is the appointment of a vigorous and effective discipline chief. The third is the energetic promotion and planning for an International Solar-Terrestrial Program (ISTP) involving the United States, Europe, and Japan by the Office of Space Science and Applications. This program would include elements of the Origin of Plasmas in the Earth's Neighborhood (OPEN) mission for which we have been waiting so long. On

the other hand, I do not believe that this budget contains a continuation of funding for payload development for this program. I note an effective decrease R&A requested here also. The concern of the Space Science Board for this discipline is expressed in the charge we have given to our Committee on Solar and Space Physics to conduct a programmatic priority study of the sort already carried out by the Astronomy Survey Committee and the Solar System Exploration Committee. We shall be pleased to share the findings of that study with you when it has been completed and would welcome any suggestions from you or your staff on questions it ought to consider.

Last July, a workshop was convened by the National Research Council under the leadership of Dr. Herbert Friedman, to review the major problems for research in the atmosphere, oceans, lithosphere, biosphere, and solar-terrestrial relations. The participants in the workshop concluded that an International Geosphere-Biosphere Program (IGBP) could provide an effective means to coordinate global measurements from space platforms and ground-based networks of the entire geosphere-biosphere system. The theme of the program would be to understand global change on time scales covering a range of a few decades to hundreds of millions of years. The workshop called for national organizations in other countries to come to the International Council of Scientific Union (ICSU) General Assembly in September 1984, with preliminary plans to implement this program. The NASA Global Habitability Program fits well into this larger international program as part of our national participatory effort—one focussed on characterizing global change on the relatively short time scale of a few decades. Of course, UARS represents a major component in the NASA program and that is one reason we are so pleased to see it in this year's budget request.

In summary, then, let me repeat how pleased I am to find three important initiatives in space science in the budget request and emphasize the hope that we shall proceed with care if we go forward with plans to establish a space station—care for the health of the space science programs.

[The following information was subsequently received for the record:]

QUESTION OF SENATOR GORTON AND THE ANSWERS THERETO

Question. Dr. Donahue, you mentioned that NASA is forming a task force on space station utilization which will be comprised primarily of members of the science community.

What effect do you think that this task force will have on the space station and its focus on space science activities?

Answer. Because the task force has not yet had its first meeting it is difficult to say how it will function and what, in the end, its effect and influence will be. If the space station is to be of the greatest possible usefulness to science there must be management structure within the NASA space station project that can respond in an effective way to the advice this task force will generate. As I said in my testimony this may involve the presence of a deputy for science in the office of an associate administrator for space station development, a project scientist in the space station project and an integral, well-defined role for NASA's science centers in the project. I hope that the task force will see its role as being one of trying to make the space station useful in the larger context of NASA's space science program as a whole.

As we have repeatedly emphasized, there will continue to be a large part of the space science program that will only be marginally related to the space station. Traditionally the strategy for space science has been laid out by the committees of the Space Science Board. On the basis of conversations I have had with Mr. Beggs and others in the administration I am confident that this tradition will continue. The task force will have to be careful not to let enthusiasm for the space station distort mission priorities defined in these station strategies. It will also have to resist temptations to compromise by attempting to adapt missions to the space station platforms that would be better off as free flyers or in orbits different than those available to the station. I hope that my friends on the task force will be tough-minded and profit from some of our experiences in trying to adapt science to the space shuttle. If these conditions are met, the task force can do a first-class service to science. I am hopeful that it will do so.

Question. Dr. Donahue, you caution that NASA should be careful to develop an adequate mix of Shuttle payloads from large facilities to small Principal Invesigator (PI) Class experiments.

Could you comment on NASA's efforts to date to achieve this adequate mix?

Answer. The NASA-University Relations Committee chaired by Dr. Frank McDonald and myself has a panel at work on this issue right now, and we are looking forrward to receiving its report next month. A lot needs to be done in this regard. There are concepts like SPARTAN and HITCHIKER in existence that involve adapting small sounding rocket-like payloads to launch from or incorporation in the shuttle. NASA is just beginning to get its first experience flying some of these. We have got to develop programs like these if the shuttle is to provide the large increase in flight opportunities for university research groups that we believe is needed. We intend to let you know about the recommendations of our Science on the Shuttle Panel after we have received and approved its report.

Question. Dr. Donahue, you have expressed concern that the proposed cap on the NASA budget over the next five years, with its built-in 1 percent growth factor, could prevent space science from expanding to the level of activity implied by the establishment of the space station.

Just what are your specific concerns about this cap impacting the level of activity of space science?

Answer. In the best of all possible worlds space science could prosper within the envelope of a NASA budget that has such a cap, even in the presence of the space station project. This would be the case if the projected decrease in the budget for Space Transportation System Operations materializes. Of course, it is the expected transformation of the shuttle to a revenue producing enterprise that would permit the accommodation of vigorous science, applications, technology and aeronautics programs along with the space station project.

The threat is that reimbursements will fall short in some years because of defections by some important potential users, or that major problems develop with shuttle systems, such as those that seem to be developing with the lifetime of the main engines, will cause great fluctuations within the NASA budget envelope. What I would like to see is an agreement that priority should be given to space programs, such as science, over the development of new means to carry out programs, such as the space station. Then, since there is no urgency about meeting a date certain at which the space station shall become operational, the space station project would be required to absorb the effects of budget fluctuations such as the one I have alluded to.

Senator GORTON. Thank you very much.

Dr. Fisk.

Dr. FISK. Mr. Chairman, members of the subcommittee, I appreciate the opportunity to present to you on behalf of the Space Science Working Group our analysis of the proposed fiscal year 1985 NASA budget.

As others have noted, there is much to cheer about in the NASA budget. The long-awaited new start for the upper atmospheric research satellite, the new start for the Mars geoscience/climatology orbiter, which is the first recommendation of the Solar System Exploration Committee, and the new start for the scatterometer mission are, together, a healthy sign of a space science program on the move again.

However, there are also reasons for concern about the NASA budget. The Space Science Working Group worries about funding for basic space science research at universities which have been an integral and vital part of the space science program since its inception.

In the 1970's we saw a steady erosion in support for basic science research. In the late 1970's and the early 1980's, we saw some precipitous declines in this support. In the last several years, due to actions by the Congress and the administration, the erosion and declines have stopped and we have begun to rebuild the Nation's capabilities in space science.

It is my function today to indicate to you where, in our judgment, backsliding has occurred in the fiscal year 1985 NASA budget, and to suggest some specific augmentations which would

correct these problems. Details on these suggested augmentations are provided in the background material I have submitted to the subcommittee.

Before dealing with these augmentations, allow me to talk about an item for which there is no cost impact in fiscal year 1985. A principal concern of universities, as Tom noted, is continuity and predictability of funding. For this reason, the Space Science Working Group supports the recommendation of the Solar System Exploration Committee that a planetary observer program be undertaken, modeled after the physics and astronomy explorer program, in which low-cost planetary missions can be flown in a regular and a predictable sequence.

In the proposed budget there is a new start for the Mars geoscience/climatology orbiter. We ask that you treat this mission as the first of the planetary observers and designate its funds as a new start for the planetary observer program.

Universities receive support primarily from supporting research and technology or SR&T funds, from advanced technology development or ATD funds, and through flight programs of which shuttle and spacelab programs are of particular importance.

Let me now express our concern about the proposed fundings in each of these areas.

SR&T funds are the bedrock on which space science research at universities is supported. The funds provide for instrument development, theoretical studies, the training of graduate students.

In the proposed fiscal year 1985 budget, there is a $5 million cut in the SR&T funds for planetary exploration. With inflation included, it is an $8 million shortfall. We ask that you restore these funds.

We have had a goal to try and restore SR&T funding for planetary exploration to the fiscal year 1981 level of purchasing power, not because this is some high point in funding, but rather this is the point at which the precipitous decline in funding began. To do this would require an additional $5 million or a total augmentation of $13 million to planetary SR&T.

Similarly, in physics and astronomy, the requirements of advanced mission development appear to have resulted in a $3 million cut to SR&T funds. We ask that you restore these funds and that you consider providing an additional $3 million to establish a dedicated theoretical program in astrophysics. There is a highly successful theoretical program in solar-terrestrial physics. A similar program is needed in astrophysics.

Likewise, in space plasma physics, which is now in environmental observations, a $1 million augmentation is required to SR&T funding to restore it to the purchasing power of just a few years ago.

A principal concern to universities is the antiquated state of our equipment. Our funding has not kept up with inflation, and it no longer allows for major equipment purchases. We are training the next generation of scientists and engineers with equipment from a past generation. This deficiency has been recognized by many studies and particularly by the recent report of the NASA/University Relations Study Group. The Space Science Working Group strongly supports the recommendation of the NASA/University Group that

$11 million should be added to the OSSA budget for the purchase of new equipment at universities.

The essence of the space science program is flight missions. And to prepare for these missions, to define the instruments and the spacecraft, advanced technology development, or ATD funds are required. There are several missions which have been strongly endorsed by committees of the National Academy of Sciences and which will be the important missions of the next few years that require additional ATD funds.

The OPEN program, which is a coordinated study of the Earth's magnetosphere, has been reformulated to be part of the international solar terrestrial program, which is a comprehensive study of the Sun, the heliosphere, and the magnetosphere, to be undertaken jointly by the United States, Europe, and Japan.

A proposed timetable for this program has been agreed to with our allies, but to meet this timetable, ATD funds are required now. But the ATD funds for this program have been cut from $2.8 million in fiscal year 1984 to $1.9 million in fiscal year 1985; in fact, $8 million is required for this mission in fiscal year 1985, or a $6 million augmentation.

Similarly, an agreement has been reached to undertake with the Department of Defense a combined chemical radiation release effects satellite, but to meet the schedule for this mission an additional $4 million in ATD funds is required.

AXAF and SIRTF are the principal recommendations of the Astronomy Survey Committee for astronomy missions in the late 1980's. The experimenters are being chosen now. But to define these experiments and to bring the missions forward as new start candidates, additional ATD funds are required in fiscal year 1985. We recommend a $10 million augmentation to the physics and astronomy ATD funds.

The final area I would like to discuss is shuttle and spacelab payloads. In large measure, the promise that shuttle would result in frequent and even low-cost flight opportunities for university scientists has been unfulfilled. A case in point is the solar optical telescope or SOT, which is a shuttle facility to make high resolution measurements of the Sun, and indeed the primary mission in this area of solar physics for the next decade.

SOT has been delayed because of problems with the space telescope, but the problems of the space telescope appear now to be solved. We urge you to authorize an additional $12 million for funding to SOT which would allow this mission to get back on track.

Similarly, spacelab payloads—OSS-2 for X-ray astronomy and space plasma lab—have had instruments under development for some years, but never receive enough funding to become flight missions. We recommend an $8 million augmentation to spacelab funding to make missions such as these a reality.

The promise of shuttle can be realized only if we achieve truly low-cost missions. One such program is Spartan, in which rocket payloads are being adapted to shuttle flights. We recommend a $5 million augmentation to develop and implement low-cost shuttle payloads.

The augmentations we are recommending for SR&T, ATD, and shuttle payloads total to $76 million, which equals 1 percent, approximately, of the proposed total NASA budget. We feel it should be viewed properly as a modest investment in the Nation's scientific and technological future.

You may ask is there a priority to these recommendations? To put the recommendations in some context, there are many additional augmentations which are important to the health of space science and space science at universities in particular that we have chosen not to address at this time. But if you ask where the pain and the need is the highest, I would suggest the following: We need to restore the funds to the planetary and the physics and astronomy SR&T, because this is our present. We need to provide the ATD funds for mission development, because this is our future. And we need to get SOT underway, because a whole discipline is in limbo without it.

These total to $45 million, and we make a special plea to you to consider funding the $11 million for equipment acquisitions, because without it we cannot do our job to educate the next generation.

I thank you for this opportunity to present the views of the Space Science Working Group.

Senator GORTON. Thank you, Dr. Fisk.

I have a long series of questions for each of you. We are simply not going to have time to ask them all here, so I will ask some, but we will submit additional questions to each of you in writing.

[The following information was subsequently received for the record:]

UNIVERSITY OF NEW HAMPSHIRE,
OFFICE OF THE DIRECTOR OF RESEARCH,
Durham, N.H., March 21, 1984.

Senator SLADE GORTON,
Chairman, Subcommittee on Science, Technology, and Space, U.S. Senate, Committee on Commerce, Science, and Transportation, Washington, D.C.

DEAR SENATOR GORTON: In your recent letter you requested that I provide answers to two questions that were raised by my testimony before the Subcommittee on Science, Technology, and Space on behalf of the Space Science Working Group on March 8. I appreciate the opportunity to expand upon my remarks, and offer the following comments:

PLANETARY OBSERVERS

Space scientists, particularly those at universities, are concerned about predictability and continuity of funding. NASA is concerned about having missions which are cost-effective. A Planetary Observer Program, modeled after the Physics and Astronomy Explorer Program, addresses both of these concerns. A line-item is established in which a series of missions is funded. Missions are then flown in a regular and predictable sequence. Inheritance of parts and block-bys are possible. By adjusting schedules, financial flexibility is available to solve problems that arise in the Program, without impacting the other non-observer missions.

The Solar System Exploration Committee recommended a fundamental change in the way we do planetary exploration. In the past, we undertook comprehensive planetary missions, each a single new start (e.g. Voyager, Galileo). The SSEC recommended that we change to smaller, more focused missions (e.g. MGCO), but that they be done in a predictable and regular sequence through an Observer Program. Clearly, the present situation, with MGCO a new start, but with no Observer Program, is the least desirable situation. The mission is limited and accomplishes only part of the science that needs to be done at Mars, and there is no commitment that needed follow-ons will occur.

As to why NASA did not choose to submit a Planetary Observer Program, I can only speculate. The Office of Space Science and Applications has fully endorsed the recommendations of the SSEC. I would suggest, then, that the problem may be with the Office of Management and Budget.

INTERNATIONAL SOLAR-TERRESTRIAL PROGRAM

NASA has had numerous meetings with our European and Japanese allies to plan an International Solar-Terrestrial Program. The President expressed concern about the solar-terrestrial environment in the Williamsburg summit communique. Yet, there is inadequate Advanced Technology Development funds in the Research and Analysis line for Space Plasma Physics to pursue adequately this program. The consequences of the deficiency are twofold:

First, it will be difficult to bring ISTP forward as a new start in FY86, the schedule that was agreed to with our allies. It would be unfair to say that a FY86 new start is impossible without additional R&A funds; nonetheless, the orderly study of the spacecraft and the experiments to be flown would be disrupted.

Second, we will send entirely the wrong signals to our allies. We are requesting that they undertake, through their planning and approval processes, the development of the spacecraft and experiments that they will fly as part of ISTP. Clearly, they will be tempted to interpret our reluctance to provide funds to ISTP as a lack of serious commitment on our part to this project.

Indeed, we once again call into question our reliability as a partner in international scientific missions. Several years ago we unilaterally withdrew from the International Solar Polar Mission. Now we raise the hopes of our allies for an International Solar Terrestrial Program, but then do not provide adequate funds to pursue it. Can we reasonably expect our allies to enter into cooperative projects with us?

I hope the above comments are helpful. I would be happy to provide any additional material.

Yours sincerely,

L. A. FISK,
Director of Research,
Professor of Physics.

Senator GORTON. Starting, Dr. Donahue with you, you were a member of the NASA/University Relations Study Group which recommended that $11 million should be added to the space science and applications budget for the purchase of new university laboratory equipment.

Can you comment on what you perceive the national or the NASA responsibility to be in the area of university laboratory equipment and on the current state of such equipment in universities?

Dr. DONAHUE. Yes. There is an almost universal problem with the equipment we have in university laboratories to train our students and to do research. It is not just a problem in space science. It runs through the entire fabric of university research efforts, and this problem has been recognized by agencies other than NASA, and there are some efforts being made to address the issue.

In the case of space science, it seems to me particularly urgent that the laboratories of the universities which are generating the experiments that are to be flown on the spacecraft for the future, training the scientists and the engineers on whom we rely for the work of this sort in the future, it seems to me essential that the laboratories at the universities be equipped with state-of-the-art equipment. In fact, if you go into the laboratories at universities, you would be scandalized to see oscilloscopes bought shortly after the Second World War are still being used and being cannibalized in order to just scrape along.

It is really a shocking state of affairs, and it is for this reason that the committee that Dr. McDonald and I chaired identified this as one of three measures, emergency measures, that should be taken to repair the state of university research in space science.

So I agree with Dr. Fisk that this is a high priority item and I am very disappointed that it did not appear in the NASA budget.

Senator GORTON. Dr. Fisk, you expressed concern about the 1985 funding level for the advanced X-ray astrophysics facility and the shuttle infrared telescope facility, and that the level included in the budget could lead to significant delays.

What would be the impact on the study of X-ray astronomy and infrared astronomy if the current budget request is, in fact, what is implemented?

Dr. FISK. Well, basically, this is a field which is simply waiting for these missions. I mean the last major X-ray satellite was HEAO–II, which is now just in a data analysis phase. And so, simply speaking, the field simply waits. And, of course, that is a difficult thing. You are trying to keep scientists interested, university groups together, in anticipation of a mission which is to come in the future.

The longer we wait, the harder that is to do.

Senator GORTON. On another subject, I understand that NASA is studying the possibility of changing the shuttle infrared telescope facility from a shuttle payload to a free-flyer, due to the success of the infrared astronomical satellite free-flyer.

Could you comment on the advantages and disadvantages of each option, with particular emphasis on the scientific return and the cost of each?

Dr. FISK. I am sorry, sir; I cannot. Maybe Tom knows.

Dr. DONAHUE. I would be pleased to.

I think that in retrospect, it never did make very much sense to try to fly the SIRTF as a shuttle facility. A long-lived facility, which flies free from all of the contamination and background interference problems that yo have in the neighborhood of the shuttle, is the only way that really makes sense to do that experiment.

Senator GORTON. So as far as you are concerned, it is not an option——

Dr. DONAHUE. That is right. It certainly should be a free-flyer, and that is a position which has been taken by the Committee on Space Astronomy and Astrophysics of the Space Science Board. We have already taken a position on that issue. I think that it should be a free-flyer, and that we should get on with defining the experiments for that mission and get it in orbit. Take advantage of the experience we have gained with IRS.

Our European friends have a mission. Their next big mission is an infrared observatory, and though it is not nearly—in my opinion, not nearly as good a mission as the one that we could fly with SIRTF.

Senator GORTON. Thank you.

Dr. Fisk, NASA reprogramed $12 million from the solar optical telescope for 1984, due to problems associated with the space telescope.

According to NASA, this was done primarily because the prime contractor for the space telescope is the same prime contractor for

SOT, and NASA wanted the contractor to resolve the space telescope problems before it began full-scale development of the latter.

Since, as I understand, SOT does not depend on a specific window within which it must be launched, was this a reasonable approach on the part of the NASA, and what is the impact of the delay?

Dr. FISK. Reason is the eye of the beholder in this sort of thing. I mean I certainly sympathize with the fact that the prime contractor was Perkin Elmer and that they were being encouraged to solve the space telescope problems and not divert their attention from SOT. That is the history.

The situation, as I understand it—and Tom Donahue indicated—is that space telescope is now rolling out the door—or will shortly—of Perkin Elmer, and therefore the problems are solved. Perkin Elmer can now reasonably devote its attention to SOT.

Again—and this is similar to your question on the X-ray astronomy—this is a mission to make high resolution measurements of the surface of the Sun, and it is the only dedicated solar mission that is being planned. So therefore, you are talking about a discipline of solar physics, studying the surface of the Sun, active field regions, solar flares, all those things, that simply sits and waits.

Senator GORTON. Thank you.

Mr. Shapley, in his state of the Union address, the President announced his initiative for space, which included a program to stimulate cooperation between the Government and industry in developing the commercial potential of space. Nevertheless, funding for materials processing in space dropped from $26.6 million for this year, $23 million for 1985.

Would you comment on this level of funding?

Mr. SHAPLEY. Yes, sir. I addressed that briefly in my statement. I think our view is that it is unfortunate that the funding has been constrained to the degree that it was. This is still a research program, and there is no exact number you can specify that would be exactly right or wrong.

On the other hand, it has been squeezed to the degree now where we are concerned that we just will not be getting what we would like to see come out of it.

Senator GORTON. But you cannot precisely identify what that difference is going to cost? It is just that it is getting very, very tight.

Mr. SHAPLEY. No, no. This is exploratory research, and the goal is to find places where materials processing in space will be useful and will make sense and will be economically attractive, or least will have that possibility in the future.

This is an exploratory program, and you really cannot predict just who will find what, or just when they will find it, but it is quite clear that the broader the program you have, the more likely you are to turn up what you are looking for.

Senator GORTON. This subcommittee in the past has supported the upper atmosphere research satellite and is pleased that NASA proposes to initiate its development in 1985.

Could you comment on its significance in terms of what it may reveal about our atmosphere, and what aspects of this project and mission warrant special consideration, or which aspects have the most potential problems?

Mr. SHAPLEY. I think that Tom Donahue can probably address the details. This is an interesting project in that it is primarily scientific, but it is classified in the present scheme of things as a space applications project. That illustrates the fact that a great deal of the science in the space science program does have direct and important applications. It also illustrates the fact that a space applications project in many ways make contributions to the science side.

I would rather yield to Tom to speak to the more technical aspects of UARS program. I think he is more up on that than I am.

Dr. DONAHUE. Well, as you undoubtedly know, the issue that the upper atmosphere research satellite really addresses is the effect that trace gases, particularly those that are produced by human activity such as the freons that are used in refrigerants, used to be used in aerosol cans, nitrogen oxides produced as a result of fixation of nitrogen in preparing artificial fertilizers—the effect of these things on an important constituent of the middle atmosphere. That is the part of the atmosphere from about 15 kilometers or 10 miles, up to about 80 kilometers above the surface of the Earth—the effect that these have on the ozone. That is the issue that is really being addresed by this satellite.

It sits way up above the ozone layer and is going to make all of its observations by remote sensing, looking at optical emissions from these trace gases, and also measuring by very ingenious techniques the wind patterns and the temperatures in that part of the atmosphere.

So it should be able to gather, on a global scale, the information we need to understand the impact that life is having on an important part of the atmosphere for the future of humanity.

I could comment in detail about the strong points and the weak points of the mission. Most of the points are strong points; there are a few weak points. If you want me to reply in writing, I will be glad to do so.

Senator GORTON. We would appreciate that.

Mr. Shapley, in your testimony, you expressed concern about the future of the Nation's remote sensing activities and about NASA's responsibilities in remote sensing R&D.

To what extent does this budget request address advanced remote sensing R&D activities, and what would be the technological international implications if NASA fails vigorously to pursue them?

Mr. SHAPLEY. Well, there is some provision in the advanced research and technology part of the budget for continuing work at the research end on future instruments for remote sensing, I have in mind at this moment the land remote sensing area.

As we understand it, there is no program in place that will lead to the flight test of these instruments, except for the flight testing that would be done on space shuttle flights. The particular orbits these instruments would be used in will not be tested because for the next several years the space shuttle will be flying in equatorial orbit rather than in a polar orbit. We are concerned that there just is not enough of a program to proceed with instrument development.

There are many ingenious advanced ideas for sensors and new tricks of the trade that are being worked on at the NASA laboratories and out at the Jet Propulsion Laboratory. But at this point this work seems to be somewhat dead-ended, in that there does not seem to be a concerted plan or a budget to move it along so that when the operational situation is straightened out, these advanced instruments can be available to the operator.

Senator GORTON. Senator Lautenberg.

Senator LAUTENBERG. Thank you, Mr. Chairman. It is always a pleasure to hear such eloquent advocates of things somewhat often seen as esoteric—essential, however, to maintaining leadership in the science areas.

One of the problems, of course, with the kind of presentation that we hear today is that with resources so limited that people who are competing for parts of the budget do not always understand the implication, the far-reaching, the long-range implication of cutbacks in areas of science. For instance, people at Princeton and other universities, have been working very hard to contribute to our Nation's knowledge in theoretical astrophysics.

And I share your concerns about the level of funding provided for research and development generally.

Could someone give us a simple explanation that others who might read this testimony at some later date—why is support for this theory so critical? What are the long-range implications of cutting back?

Dr. FISK. A couple of years ago, NASA established something called the solar terrestrial theory program. This was in solar terrestrial physics. And there is a simple recognition that there is an evolutionary understanding. You go up and you fly missions and you collect data. You interpret the data. But then, to get closure on it, you have to understand the data; you have to essentially put the data into some physical understanding. That is where the theory comes.

You essentially take an amalgamation of many different missions, many different ideas, and formulate it into some understanding that basically tells you how the process you are observing works.

In the beginning of the space program, we really emphasized flying of missions because we were exploring everything that was new, and anything came out of it was just interesting because it was new. But to get understanding, you have to work the data over, develop theoretical ideas for it.

This was recognized in solar terrestrial physics. One of the reasons that came first was that was the oldest of NASA's disciplines. One of the first things we did in space was just to go into the near space environment.

Astrophysics is now coming along in a similar way. We are making lots of measurements with Einstein, we are going to make more measurement with space telescope. AXAF and SIRTF will be making more measurements still. But you cannot just measure things; you have to try and understand them. And to understand them, you have to do theory.

And so the feeling is that it is NASA's obligation, if it really wants to make use of this data that we have used the taxpayers

money to collect and all this effort to do so, they need to provide a supporting theoretical program which develops along with the collection of the data, makes use of it, puts it in an understandable form.

Senator LAUTENBERG. An essential of the ATD program is that the essence of space science progress is a flight mission.

Mr. Shapley, I note in your testimony that you agreed with the earlier panel, the previous panel's comments about ACTS.

There also is a $7 million cut proposed for communications research generally. What kind of impact does this have, in your view, on the cutbacks in this area? Is it essential in the perspective of things as we go?

Mr. SHAPLEY. In the communications area—well, in each of these areas—you have to move ahead with the research, the ground development, and then punctuate that periodically with flight tests. I think that it is terribly important to continue the ground-based research in the communications area; there is no doubt about that. But there is also the need at this time to move forward with the ACTS program for flight testing.

Senator LAUTENBERG. I did not want to confuse the issue. I think my question might have. Initially my concern was about—as you perhaps heard if you were in the room before—about eliminating the flight testing for ACTS, which I think is essential in terms of trying to prove theory and the hypothetical arrangements already developed.

The other concern was, of course, the general cutback in communications research.

Is there any yardstick available of what other developed nations are spending as a share of budget on space applications, R&D in space?

Mr. SHAPLEY. If there is, Senator, I am not aware of it. I do work a good deal, with my other hat on, with statistics on research and development. At the American Association of the Advancement of Science, for each of the last several years I have gotten out a little book which tries to explain what is going on in R&D. But R&D statistics are very hard to come by on an international basis, and once you get them, you really do not know whether you have the full picture. You have mixtures, you see, of expenditures by Government and by private companies, which frequently will not reveal how much they are spending in a given field, so it is very hard to get a gauge on that.

You can judge it better in some fields than in others. For example, in the remote sensing field, with the French going ahead with the Spot satellite, the Japanese going ahead with theirs, we have obviously the visible manifestations of a strong, ongoing research and development program. We see more of it perhaps in the results than we know about it in terms of how much money they are putting into it.

Senator LAUTENBERG. Dr. Donahue, do you have any observations—you mentioned our neighbors and the French doing work in areas that were not, as I understood your comments, sufficiently funded.

Is there any specific indicator that tells you we are, as a nation, with our size and our resources, doing more or less than others in space science research?

Dr. DONAHUE. Well there are some exciting programs that are being developed by the Europeans in space science, by ESA, the European Space Agency, by the Japanese, and certainly by the U.S.S.R.

I would not denigrate, however, the U.S. space science program by saying, as some are tempted to say, that is in risk of becoming inferior compared to the programs that are being carried on by these other groups. The ESA program is just a tiny program compared to the U.S. space science program. The Soviet program is something else again, and what the Soviets have in comparison with us at the present time to boast about is that they are flying things, they are actually flying missions, they are launching missions to Venus and into the Earth's atmosphere, to the comets, and we have been standing and waiting for quite a while to get our missions launched.

In fact, a colleague of mine encountered the head of the Russian Space Institute at a little conference in Tokyo a couple of months ago, and asked our Soviet colleague about the status of Soviet planning for future science missions, and Professor Sadhdiev responded by saying, "Well, you know, we do not have much time for planning; we're doing things."

Unfortunately, as I have repeatedly said here, we have had a long hiatus in launch of the missions that we are preparing. Once we get going on those things, our space science program is going to be a very exciting program. What we are asking for is that we get on with it and get started, and continue to launch at the rate that we used to launch at.

Dr. FISK. Senator, if I could add one more dimension to Tom's comments, I think one of our concerns in international space programs—there are many areas where it makes sense for us to cooperate in space, and I think that there is an area that we would all mutually benefit from.

And I think one of the concerns we have in the scientific community is that NASA appears to be a reliable partner in those cooperations. A few years ago we had a very disastrous experience with the international solar polar mission, where NASA unilaterally withdrew from it, and that left our European colleagues quite annoyed.

One of our concerns over getting adequate ATD money for the international solar terrestrial program is that we have started discussions with our European colleagues and the Japanese over the possibility of doing this large international program, and we have encouraged them to believe that we will be able to participate with them, with the usual provisos that congressional approval and so forth is required.

But then we turn around and we do not put adequate ATD money into fulfilling even the minimum requirements of bringing that mission up to a level of development where it can be brought forth from a new start.

It is my own judgment that signals again that we are perhaps not a reliable partner for international cooperations, from which we will ultimately be the losers.

Senator LAUTENBERG. Thank you, Mr. Chairman.

Senator GORTON. I would like to thank the members of this panel for their help as well.

And we will now hear from our last witness for the day, David Yoel, president of Getaway Special Services, Inc., if he will come forward.

STATEMENT OF DAVID W. YOEL, PRESIDENT, GETAWAY SPECIAL SERVICES, INC.

Mr. YOEL. Thank you for the opportunity to express my views on the future of materials processing in space and of NASA's interactions with small companies.

Getaway Special Services is a company dedicated to providing low-cost hardware to users of NASA's small self-contained payload program.

One of the exciting new goals of the American space program is the commercial manufacture of materials in space. The value added to these materials is potentially significant. The improvement of materials already in use, and the creation of new materials impossible to make on Earth can have a far-reaching impact on our society. It can improve the products we create and place us permanently in the environment of space.

The first materials processing in space experiments were conducted during the Apollo program some 15 years ago. Since then, other NASA programs have continued to explore this area. Until the shuttle era, only 100 hours of experiments had been conducted. Now, for the first time, an operational shuttle fleet provides us with significant in-orbit resources, extended scientist participation, and the capability to return materials to Earth.

Experiments already conducted on the shuttle have demonstrated the benefits of materials processing in space. The dawn of a new industrial age is upon us. Although we did lead the way, other countries appear to have a much clearer vision of the future of materials processing than does, generally speaking, the American scientific and technical community.

Because of the cost involved with processing materials in space, the benefits must be great for materials processing to be economically feasible. Hundreds of materials are being considered. At present, the three general categories of materials that show the greatest promise are pharmaceuticals, crystals, and glasses.

The list of candidate materials is large, but its limits reflect our still limited understanding of the practical details of processing these materials on Earth or in space. Only a small number of materials have been tested, and yet the results have been impressive.

In some cases, the improvements have been expected. For example, in the McDonnel Douglas pharmaceuticals experiments aboard the shuttle, some 480 times greater yield was achieved at 5 times the purity in urokinase production. In other cases, the improvements have not been expected. For example, in the germanium selenide experiments by Dr. Wiedemeyer, crystals, some 10 to 100

times larger than those grown on Earth, were achieved at 4 times the predicted growth rate.

This was not a result that was predicted by theory, and they are searching around now trying to find a theory to apply to it. Some of these results just cannot be predicted yet by scientists.

These improvements are due to the reduction or elimination of the gravity-induced effects in the solutions from which these materials are solidifed or extracted. The effects include bouyancy, sedimention, hydrostatic pressure, and buoyancy-driven convection. Again, their removal has already led to processes of enormously greater yield and materials of much greater purity and greater uniformity.

Once a candidate material and process have been selected, at least 3 years are required to develop an initial space flight experiment. Typically, a small quantity of material would be grown. An experiment of this type is necessary to prove the concept, quantify process parameters, and to determine the value of the material. Several experiments may be required to develop a practical process.

More than 5 years are required before salable quantities are produced in the best of circumstances, and an even longer period before an initial payback.

A development program of this nature is never inexpensive, even though on a typical aerospace scale these systems are small. The financial exposure could become significant. During such a program, ground base processing also moves forward and creates an additional risk. Materials processing in space is not yet a mature commercial area.

Many in the growing commercial space community, though, look to aerospace companies for leadership in this field, believing that they are the natural developers of these materials, since they are most familiar with space.

Aerospace companies, though, are typically users of materials; they do not make the materials they use. Further, these companies are organized for Government contracts, not for small commercial programs. Therefore, these companies do not typically provide the optimum environment to develop commercial materials processing.

Another anticipated approach is the dedicated company formed with venture capital investment. Unfortunately, venture capitalists are typically interested in "slam dunk" type investments. In other words, you put the money in, and within 6 months or a year the money starts pouring out again. There are many areas in which they can find those kinds of investments. They capitalize companies with short-term potential for return or to re-capitalize companies with a 20-year profit and loss statement. They are businessmen, they cannot afford to tie up their resources for extended periods of time. They do not always understand the technical details involved, so they seek indivduals or organizations with established credibility in the field.

Who might these experts be? Unfortunately, the commercial materials processing industry just now emerging, is young, and there are few in it at present. The established scientific community has taken a dim view of materials processing in space and has very little interest in the field. They believe that although MPS may

hold promise in the future, many more years of R&D are required before a serious funding commitment should be made.

In the materials industry developments have generally come about empirically, not theoretically. And the space environment is beyond the materials industry's experience. Their technology is indeed art as much as it is science. Besides, with all their resources committed to Earth-based processes, Earth-based plant and equipment, it would, at best, be difficult for these established companies to endorse or invest in this new area. There are few, if any, companies then that would be obvious developers of commercial materials processing in space.

Perhaps the scientific community is correct. As slow and steady development program leading to eventual production may be the appropriate course. The problem is, though, that we have competition. The Soviets have boasted repeatedly of the substantial materials processing in space activities in their already-existing space station, and our Western allies are moving ambitiously in this field.

Twenty-eight of the thirty materials processing in space experiments aboard Spacelab I, for example, were of European origin. The West German SPAS and MAUS programs have already flown at least 6 materials processing experiments, and have roughly 25 more scheduled. In 1985 the shuttle will carry Spacelab D-1. The entire flight has been purchased by the West German Government. It will reportedly contain 250 materials processing experiments. They are all proprietary. They are walking away with the entire industry.

One of the things that made America a great industrial power was our capture of the steel industry from England. Germany and Japan have now taken the lead in that industry. I do not advocate hindering the activities of our foreign allies in this field. I advocate competing. The United States should be a user of space in the future. We should be more involved than to just provide the transportation and services the others need in fufilling their goals, although this is where American commercial interests seem to be pointed.

There are a number of ways we can improve our competitive potential, but your vision is required. In the past, the Government has subsidized emerging ventures when they have seen a national need such as the railroad synfuel and the nuclear industries. Perhaps this is such a time. The focus should be on reducing the financial exposure in the long period of uncertainty associated with these private investments.

Although I do not believe any of these can replace industrial vision, I offer the following suggestions for your consideration: A significant increase in the NASA MPS funding——

Senator GORTON. Mr. Yoel, you have about 1 more minute left. So if you will summarize that, we will include the balance in the record.

Mr. YOEL. Thank you.

I believe a significant increase in the NASA materials processing funding level would be very important at this time. This can help find the candidate commercial materials that industry might consider.

The next logical step beyond the getaway special type program is the Hitchhiker which is now under consideration. I urge you to support it fully. It provides more shuttle power and other resources than does the getaway special.

Materials processing in space will emerge as a new industry in the years to come. America started the fire, and now we are watching others learn to make it burn brighter. We need your vision to ensure that our opportunities continue in the future in this area.

In closing, I would like to quote James Michener from his recent book, Space: "An age is called Dark not because the light fails to shine, but because people refuse to see it."

Senator GORTON. Thank you very much, Mr. Yoel. As I said, your entire statement will be a part of the record.

And I have some questions that your testimony has triggered. I will ask you a few now.

Mr. YOEL. It would be my pleasure.

Senator GORTON. You alluded to the fact that the European activities in materials processing in space have met, if not gone beyond, those of this country.

What lessons should we learn from our European and Soviet counterparts that might improve our own materials processing?

Mr. YOEL. Well, I think the basic issue involved is vision. They understand the fact that empirical developments in materials are the typical way in which improvements are attained. The theory always follows, generally speaking. I think faith in experimental study, rather than a total reliance on initially producing theoretical results perhaps would be one of the lessons.

Senator GORTON. Thank you.

The President announced a comprehensive space plan which includes a permanently manned space station to be operational early in the next decade.

What impact can this space station have on space manufacturing and materials processing in space?

Mr. YOEL. In the production of materials in space, the benefit one really seeks is the microgravity effect. Experiments already conducted on the shuttle have utilized this, but they have indicated that the best times to do these experiments are when the astronauts are sleeping or when some inactive period is in process.

Typically, I think what is going to happen is that these materials are going to be processed in separate free-flying units, man-tended every couple of weeks. They would fly several hundred yards over to the station, or astronauts would go over to them and extract the processed materials and prepare them for return to Earth.

Again, I think the use of a man-tended free-flyer is probably, in production, the kind of use a space station would have in commerical materials processing. In materials research and development, I think a space station can have significant impact in that scientists and technicians will have the opportunity to participate in the experiment.

Senator GORTON. Looking into the more distant future, it has often been mentioned that a manned space station could ultimately lead to the development of a lunar base.

What unique opportunities could a lunar base in space manufacturing and materials processing?

Mr. YOEL. I do not have a very detailed understanding of the materials available on the Moon's surface. But from what I understand, the majority of the materials are materials like aluminum, and titanium, all in oxide form, iron, and that kind of thing. And those materials could be used for the fabrication of lunar or other structures.

I presume that there are some significant trace materials available that might be valuable, but when you arrive at the moon's surface then, of course, you have one-sixth gravity and that does have a significant impact on the gravity-driven processes.

Senator GORTON. Its use, then, would be quite different from that of a space station.

Mr. YOEL. I believe it would be; very much so.

Senator GORTON. You mentioned that NASA should be more consistent in its getaway special manifesting policy.

Could you elaborate on the manner in which NASA has implemented that policy and how it might improve it?

Mr. YOEL. Well, the manifesting policy is a bit vague, and I think that one of the main reasons for that is to give them latitude in getting the largest number of people onboard. It is easily misinterpreted, and I had apparently misinterpreted it in the recent past, so that was as much a mistake on my part as anything.

They do the best they can in that area. The Getaway Special program is set up such that one is not assigned a specific flight until the payload is very near complete, and so there are some very frequent last-minute deletions or additions of payloads from a particular flight. And that does cause headaches sometimes for small users.

[The statement follows:]

STATEMENT OF DAVID W. YOEL, PRESIDENT OF GETAWAY SPECIAL SERVICES, INC.

One of the exciting new goals of the American space program is the commerical manufacture of materials in space. The value added to these materials is potentially significant. The improvement of materials already in use and the creation of new materials impossible to make on Earth can have a far reaching impact on our society. It can improve the products we create, and place us permanently in the new environment of space.

The first materials processing in space (MPS) experiments were conducted during the Apollo program more than 15 years ago. Since then, other NASA programs have continued to explore this area. Now, for the first time, an operational shuttle fleet provides us with significant in-orbit resources, extended active scientist participation, and the capability to return materials to Earth. Experiments already conducted on the shuttle have demonstrated the benefits of MPS. The dawn of a new industrial age is upon us. Although we did lead the way, other countries appear to have a much clearer vision of the future of MPS than does, generally speaking, the American scientific or industrial community.

Because of the cost involved with processing materials in space, the benefits must be great for MPS to be economically feasible. Hundreds of materials are being considered. At present, the three general categories of materials that show the greatest promise are pharmaceuticals, crystals, and glasses. The list of candidate materials is large. Its limits reflect our still limited understanding of the practical details of the processes involved in the creation of these materials—on Earth or in space. Only a small number of materials have been tested, and yet, the results have been impressive. In some cases the improvements have been expected, in others they have not. These improvements are due to the reduction or elimination of the gravity-induced effects in the solutions from which these materials are solidified or extracted. The effects include buoyancy, sedimentation, hydrostatic pressure, and buoyancy-driven convection. Their removal has already led to processes of enormously greater yield,

and materials of much greater purity and greater uniformity than have been achieved by their counterparts on Earth.

Once a candidate material and process have been selected, at least three years are required to develop an initial flight experiment. Typically, a small quantity of material would be grown. An experiment of this type is necessary to prove the concept, quantify process parameters and to determine the value of the material. Several experiments may be required to develop a practical process. More than five years are required before any profits can be achieved, in the best of circumstances, and an even longer period before a return on investment is reached. A development program of this nature is never inexpensive. The financial exposure can be significant. During such a program, ground based processing moves forward. The risk can become great.

Many in the growing commerical space community look to aerospace companies for leadership in this field, believing that they are the natural developers of these materials since they are most familiar with space. Aerospace companies are typically users of materials, they don't make the materials they use. Further, these companies are organized for government contracts, not for small commercial programs. Therefore, these companies don't typically provide the optimum environment for commercial MPS.

Another approach is the dedicated company formed with venture capital. Venture capitalists are typically interested in "slam/dunk" investments though, to borrow a phrase from basketball, or they recapitalize companies with a 20 year profit and loss statement. The venture capitalists are businessmen, they don't always understand the technical details of the field, so they seek individuals or organizations with established credibility in the field. Unfortunately, the emerging MPS industry is young and there are few in it at present. The established scientific community, by and large, has taken a dim view of MPS. They believe that although MPS holds promise, many years of R&D are required before a serious funding commitment should be made. Developments in the materials industry have generally come about by empirical, not theoretical, methods, and the space environment is beyond their experience. Besides, with all their resources committed to Earth-based plants and equipment, it would, at best, be difficult for these estabished companies to endorse or invest in this new arena.

Perhaps the scientific community is correct. A slow and steady development program leading to eventual production may be the appropriate course. The problem is that we have competition. Not only have the Soviets boasted repeatedly of their MPS activities on their already existing space station, but our Western allies are moving ambitiously in this field. Twenty-eight of the 30 MPS experiments on spacelab 1 were of European origin. The West German SPAS and MAUS programs have already flown at least six MPS experiments and have roughly 25 more scheduled in the near future. In 1985, the Shuttle will carry Spacelab D–1. The entire flight has been purchased by the West German government. It will reportedly contain 250 MPS experiments. They are all proprietary! They are walking away with the entire industry! One of the things that made America a great industrial power was our capture of the steel industry from England. Germany and Japan have now taken the lead in that industry from us. I don't advocate hindering their activites in MPS, I advocate competition. The United States should be a user of space in the future. We should be more involved than to just provide the transportation and services others need in fulfilling their goals.

There are a number of ways we can improve our competitive potential. Your vision is required. In the past, the government has subsidized emerging ventures when they've seen a national need, such as the railroad, synfuel, and the nuclear industries. This is such a time. The focus should be on reducing the financial exposure and the long period of uncertainty associated with private investments. I offer the following suggestions for your consideration:

1. A significant increse in the NASA MPS funding level would be a great step forward.

2. Another aid would be for NASA to improve its ability to deal with the "small" company. On NASA's typical scale, MPS systems are small and will likely be so for many years. NASA has spent more than a quarter of a century working with large companies on large programs. Further, NASA has almost always been the customer. They are quite naturally accustomed to and best organized for such interactions. NASA is making the effort, and they are learning. They have much more to learn. At its very highest levels NASA has made a commitment to commercial MPS. It will take some time for that commitment to work its way through the entire organization.

One method NASA is using toward that end is the Getaway Special (GAS) program. William R. Lucas, Director of NASA Marshall Space Flight Center, has said, the ". . . GAS program may be the prototype for doing business in space." The GAS program provides the lowest cost approach ever to performing experiments in space. It is also amenable to rapid development and reflight. Further, it has the effect of planting seeds of new ideas in the minds of its users, which include universities, individuals, private industry, and the government itself. In the GAS program, the customer buys, at modest cost, an opportunity to fly their own experiments in space. Although GAS payloads are small, much can be done in them with a little imagination. Perhaps the major benefit of the program is that it teaches the people "in the trenches" at NASA how to deal with a new breed of customer; the small, paying customer. I believe the GAS program is excellent and a great asset. By increasing the consistency of the manifesting policy, increasing its staff, and continuing to expand the scope of the GAS program, NASA could further improve it.

3. The next logical step beyond the GAS program in payload size and capability is the "Hitchhiker" payload of opportunity program. I urge you to support it fully.

4. Extra tax write-offs on future profits to offset the high risk.

5. The government could provide some of the seed money required so that investors would know a program has the government's endorsement. Presently, NASA just provides free shuttle rides, this doesn't seem to be sufficient.

6. The government could subsidize these emerging ventures with the understanding and agreement that the monies will be paid back with interest from future earnings.

Materials processing the space will emerge as a major new industry in the years to come. We started the fire, and are now watching others learn to make it burn brighter. Your vision is needed to insure our flame doesn't go out. In closing, I'd like to quote James Michener from his recent book, *Space*. "An age is called Dark not because the light fails to shine, but because people refuse to see it."

Senator GORTON. Thank you, Mr. Yoel. We appreciate your lending us your time here today.

And with that, the meeting is adjourned.

[Whereupon, at 11:38 o'clock a.m., the hearing was adjourned.]

NASA AUTHORIZATION FOR FISCAL YEAR 1985

THURSDAY, MARCH 29, 1984

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:33 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding.

CLOSED SESSION

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. I call to order this authorization hearing of the National Aeronautics and Space Administration on the part of the Science, Technology, and Space Subcommittee.

The Congress recognized the dual civilian and defense activities of the Nation in space and aeronautics in establishing NASA in 1958. The National Aeronautics and Space Act of 1958 specified that NASA should make available to our national defense agencies information of value and significance to those agencies and, in turn, that our national defense agencies should furnish to NASA information about discoveries that have civilian signifiance.

It is in the course of developing our fiscal year 1985 authorization for NASA and in recognition of the close relationship of our civilian and defense aeronautical and space activities that we are holding this hearing today.

The balanced relationship that has been maintained between NASA and DOD has contributed to our Nation's preeminence in both aeronautics and space in both civil and defense realms. There is at this time no equal in the world to this unique capability for science, civilian applications, and national defense.

We now face new challenges which require an appraisal of this NASA/DOD relationship if we are to meet the competition in space science and applications, in commercialization of space, and in the militarization of space.

Our purpose in today's hearing is to review our national defense activities in aeronautics and space in order to determine how these impact or are impacted by NASA's proposed fiscal year 1985 program.

The issues of mutual concern are many: The composition of our national space transportation system, the requirements of a permanently manned space station, the development of mutually appro-

priate upper stages for the space shuttle, and the continued advancement of both military and civilian aeronautics.

There can be no question that the decisions which are made in response to these concerns will be difficult and critical. Certainly our position in aeronautics and space is more directly and aggressively challenged than ever before.

With these thoughts in mind, I am pleased to welcome to this hearing Dr. Richard DeLauer, Under Secretary for Research and Engineering in DOD, and Dr. Robert S. Cooper, Director of the Defense Advanced Research Projects Agency. Both of these gentlemen have appeared before this committee previously and I welcome them here today.

Dr. DeLauer.

STATEMENTS OF DR. RICHARD D. DeLAUER, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING; AND DR. ROBERT S. COOPER, DIRECTOR OF THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, DEPARTMENT OF DEFENSE

Dr. DeLauer. Thank you, Mr. Chairman. I appreciate the opportunity to cover our science, technology, and space activities with you, particularly those activities that have to do with interaction with NASA. I request that my detail statement be submitted for the record and I will just have some introductory remarks and get on to any questions that you may have.

Senator Gorton. By all means. Your entire statement will be included in the record.

Dr. DeLauer. Thank you.

We continue the strong relationship with NASA that we have testified to in the past, and this year we will not only continue some of the programs we started in prior years, but we are going to try to institute some new collaborative efforts.

To refresh your memory, both in the defense and civil areas we are cooperating with them on the space transportation system, Centaur, dual use of the Vandenburg facility, and nuclear power for space. The latter program is now an established effort and a cooperative one, along with DOE. We are working with the Navy. The Navy is working with them on their remote sensing in the oceanography area. We are starting to do some work on transatmospheric vehicles and hypersonic vehicles. When we look to the future for both of these efforts we see some interesting things.

We have an advanced technology demonstration airplane. You might have seen pictures of it—the forward-swept wing. I think the present nomenclature is the X-29. A program that is most interesting is the JVX, which uses a tilt-rotor concept and it is primarily for utilization by the Marine Corps, but its applications cover the broad area of vertical takeoff and high-speed transit is obvious. That program is solid and surviving a rexamination of the budget in light of the present situation. The Navy is reponsible for the JVX.

We are doing work in new engine concepts, and more work in rotor technology. We are conducting research on an X-wing concept which gives us an opportunity in many of our activities needing low observable aspects. We continue with our Aeronautics and As-

tronautics Coordinating Board, the one that Hans Mark and I co-chair. That is the forum from which we handle most of our interactions. We are talking to each other all the time.

In keeping with things that were the committee's concern in the past, let me briefly give you a recap of the Soviet activity for the year 1983. They have expanded their activities in 1983. They put [deleted] in orbit, and we expect them to continue. On any given day, the Soviets have between 95 and [deleted] satellites on orbit.

During 1983 we saw a demonstration of increased capability on a heavy lift vehicle of our old Saturn class, another that is like our 34D Titan, which is a medium size. They have now developed the capability for reusable transport system. We have got good photography of their space plane, taken by, I think it was, an Australian patrol aircraft. It showed them during the recovery process.

No question about it, they have already got a permanently manned space station and now they are starting to transfer material to it.

[Deleted.]

In 1983 there was no real RORSAT activity, probably as a consequence of the problems they had in 1982, but we do not expect that inactivity to persist. They will fix the problems and we will be looking for them to go ahead with the RORSAT.

[Deleted.]

The second manned space flight for *Salyut 7* occurred in 1983, [deleted] another manned space flight was *Cosmos 929*, and that was the space station module and it carried approximately 3,000 kilograms of supplies and this vehicle has been announced by them as a multipurpose vehicle capable of use at a tug or a module or free-flight spacecraft.

That is kind of quick recap of the Soviet activities in 1983. How about ours?

We are continuing to look at quite a few resources in space in the 1985 budget. There is close to $13 billion for space programs including DOD space programs. This is a large increase, 22 percent over 1984, and it is significant that a lot of our space programs that were initiated early in the administration are now getting to the point where they take quite a few resources.

A year ago we discussed with each other the operation, the establishment of space operations in the Air Force through the formulation of the Air Force Space Command. In October, the Navy established a Naval Space Command, headed by a former astronaut, Commodore Dick Truly. Two of its major operational responsibilities are Navy navigation satellites and their space surveillance system.

In October of this year, 1984, the Navy Space Command will have responsibility for the Navy SATCOM. At the same time, the JCS formed a joint planning staff for space in February of this year. This is a significant step; notwithstanding all the work we can do with space, until the activity really gets folded into what you would call the military planning, it is really not part of the military system as a warfighting capability. With the JCS taking on this role, there will be more and more.

Senator GORTON. What function does the Army play in this regard?

Dr. DeLauer. The Army has representatives as part of the JCS.

Senator Gorton. No separate command?

Dr. DeLauer. No separate command yet, no. Right now we have get two. There is some discussion with regard to maybe having one that will come probably later.

I think much of this, and I will mention a little bit, will determine how the President's strategic defense initiative fits into this whole question of interaction into the command structure. It is a thing that is overlooked both by the popular press and even more of the scientific people.

For the strategic defense inititive to have, in the long run, the capability the President's initiative and goals require, it has got to be folded into the command and control and battle management structure of the Department of Defense. If you do not, it cannot be used in the manner that we intended.

Our ASAT is in test. The first flight occurred in January and the second flight test will be in [deleted]. This flight will be against a maneuvering vehicle and it will be—they will have—a STARSAT sensor calibration will all be demonstrated in the [deleted] flight.

One of the problems that still remains to be addressed is this whole question of launch vehicles and access to space. The national policy is that we use space transportation, that is, the shuttle, for all defense access to space. When you look in detail at some of our requirements, it is starting to become obvious that both from an economic standpoint, the cost of operating the shuttle, as well as the nature of its availability and also the contingency process, that we should be looking at expendable launch vehicles as part of this ability to be able to have access to space.

It is a question that has broad dimensions. What class do you develop? What might the uses be? There has been discussion about having a commercialization of expendable launch vehicles. We know the decision was made that is part of the Transportation Department's responsibility now. They are in the process of developing a plan. On the other hand, it is not clear that what might be a commercially viable launch vehicle program to compete with Arienne in Europe that would really satisfy some of our hard payload requirements necessary for the Department of Defense. That has to be studied and looked at.

The fact that the President has taken the initiative in establishing a program for the space station has changed at least the near-term requirements for what is necessary for high payload in two orbit requirements. Our strategic defense initiatives also have changed some of our timing in regard to what we need for launch vehicles.

So this is going to be a question that has to be resolved. I would be misleading you if I said we had unanimity of opinion; we do not, even within the Defense Department, let alone between us and NASA and between us and NASA and the Department of Transportation. But it is a subject that has to be addressed because of economic implications and also the ability to be able to pursue these programs in the long term whether or not we can get things in the right places at the right time.

Let me just quickly cover a few things that we are doing with NASA. I mentioned a few. I do not think I have many more to add.

I might give you a little bit of information with the fact that I think we now have identified the IUS failure problem, and late this year we are planning to have a flight to check out what we think is the problem with the IUS.

In aeronautics, as I mentioned before, most of the advanced stuff has to do with transatmospheric flight, as well as—it goes to two extremes—transatmospheric flight down to some of the new concepts for vertical takeoff and landing and flight control activity. The X-29 is really two things. It is a new approach to understanding the characteristics of forward-swept wings. At the same time, it is providing a test bed for advanced flight control systems.

I think that I will defer now to Bob Cooper, if he wants to finish up some of the things DARPA is working on, and then we will open it up to questions.

Dr. COOPER. Thank you, Mr. Chairman.

DARPA has broad programs in space and aeronautics in which we work very closely with NASA. We have a history of close cooperation with NASA, particularly in the aeronautics area. Our two largest programs right now with NASA are the X-29 program and the X-wing program. Later on this year we will be shipping the first of the X-29 vehicles out to Edwards Air Force Base to the NASA Dryden flight facility and NASA will begin to take over the flight testing part of the program after Grumman has demonstrated the first four flights.

During this past year, we have been working vigorously with NASA on the X-wing program to develop and install an advanced circulation control rotor system on the rotor system research aircraft that NASA has at the Ames Research Center. We will be testing in about 1½ years, this very advanced concept for rotary wing aircraft, where the aircraft can take off vertically and then transition into forward flight and actually stop the rotor and the rotor then becomes a fixed wing—two wings are slanted forward and two slanted aft in an aft-swept configuration—with the circulation control system providing the lift in that system—a very advanced concept which has potential to fly at high subsonic mach numbers.

We work with NASA directly on these programs, and NASA, particularly on the X-wing program is providing substantial joint funding with DARPA.

In addition, DARPA has a number of space activities, among which are the Teal Ruby advanced surveillance technology spacecraft. This will provide for the first time, massive two-dimensional focal plane infrared arrays that will look down into the atmosphere and be able, we hope, to track air vehicles from space using infrared technology.

NASA is quite interested in this technology. Typically in the past DARPA has provided to NASA scientists infrared detectors for use in scientific observations of space objects, focal planes that have been developed using DARPA technology. We have very close cooperation as well with the scientific parts of NASA in astrophysics and astronomy areas.

DARPA is a strong and vital organization and in part it is so because of the relationships we have held with NASA, and we will continue those relationships in the fiscal year 1985 budget year.

Dr. DeLAUER. Mr. Chairman, let me just kind of finish up with a little bit of a request. We in DOD are trying the best we can with our resources to assure that the future is at least partially preserved by the education of young new scientists and engineers. Seldom do we get a chance to talk to other committees that also, I think, should be concerned about this problem.

I just hope that this committee will take on as an assignment, if you have not already planned it for this year, a good look at the strength, at the good health, at the ability of our universities and secondary schools to provide the replenishment of something this country has had over the years. That is a massive group of excellent technical personnel.

I think that we are falling behind. We are falling behind not only in the security area but in the private area. The Japanese outproduce us in engineers. The produce more engineers. They produce as many engineers as we produce lawyers. Now that is a bad tradeoff.

And I hope that this committee will take that on as an assignment, to see that we are putting enough of our Nation's resources into keeping ourselves strong in the training and technical areas. We have some initiatives in the Defense Department, but we are limited in what we can do. As you are well aware, we represent about 8.5 to 9 percent of the manufacturing GNP in this country. We only represent about 3 percent of the electronics GNP in this country, even though we might be on the leading edge of the technology.

The need of the armies is great, but so is everyone else's, and with that I will close and take questions.

Senator GORTON. Thank you, Doctor.

Were the factors that have now led the Air Force to decide to purchase of commercial ELV's beginning in fiscal year 1988 obvious before the administration's 1983 decision to phase out Government use of the ELV's?

Dr. DeLAUER. No. I think a couple of things have happened in regard to that situation. I think the question, as you know, during the 1982 period was whether the fifth orbiter was going to be built. When it became obvious that the fifth orbiter was not forthcoming as rapidly as people thought, and then when you look how the STS was configured, we do not have complete capability on all STS's, all four of them, to handle our payloads, you can see the problem.

And so the basis for reexamining this access to space came as a consequence of looking at the out-year requirements for certain of our payloads, and where they went to.

Senator GORTON. Would the decision have been different had we authorized a fifth orbiter?

Dr. DeLAUER. Personally, my contribution to the decision would have been different because I was trying to get us to require NASA to modify even the fourth one, because it just did not have the capability for certain payloads. On the other hand, while the Secretary has made that policy and has promulgated it for the ELV's, I tried in a general way to change the policy by saying look, we need to reexamine that. Three things have contributed to that reexamination.

One, the space station decision by the President, which put requirements for unmanned vehicles in a different light and a different time scale; two, the agreement and the focus of the strategic defense initiative which would need high payload-capable launch vehicles, and three, the budget problem.

One of the problems with the expendable launch vehicle program now being configured by the Air Force is the question of what are the economic implications of the contingent liabilities? It is one thing to say that we will be very happy to be the angel to get the commercial ELV program off the ground—no pun intended, but it is another to question economic viability of the future versus our contingent liability of what happens if it is not realized. This is something I want my boss to reexamine.

And we are in the process of trying to do that.

Senator GORTON. With respect to those economic and budget considerations, if NASA cannot obtain customers for future shuttle missions because of this ELV decision, is DOD prepared to help NASA either with some such payloads or directly?

Dr. DELAUER. Well, I think it is hard for me to answer that other than to say we probably would have to since we are still going to be able to be dependent on certain of our access through the shuttle. We will certainly do it just by the ratings. We are going to have so many of them, and it is going to cost so much to maintain them. If we were a customer and the number of payloads per year that are going to be launched, you know, it is a very simple economic question—the cost divided by the customers.

And that tells you what each customer has to pay, so it is a self-evident truth. What we should be doing, and working hard to do, is to try to get the cost per pound of those payloads down so that one can budget for it and it can be affordable.

The economic analysis, whatever assumptions, just as you have made, to know how many customers we are going to have, tells you right off the bat whether you are going to price yourself out of the shuttle market or not. That is a question that has to be asked, before we make commitments on payloads.

But we have got competition with the Europeans.

Dr. COOPER. I think that Dr. DeLauer has really struck on the basic issue. Back in the late 1970's when I was the Director of the Goddard Space Flight Center, Goddard controlled the Thor-Delta launch vehicle program, which was then the largest launch vehicle program that the Nation had because it served the commercial communications satellite market, mainly civil launches, although there were many scientific and some NATO communications satellites launched by that system.

We planned vigorously in the 1977–78 time period the shutdown of that system. It was national policy from 1972-onward to phase out the expendable launch vehicles, all of them, including the ones that would serve the commercial market, including the Delta and our plan was to have completely phased out the Delta program by 1982.

Well, here we are in 1984 and the Delta launch vehicle program is still going at a tremendous clip. There is strong interest by the commercial sector to pick that launch vehicle up and to continue its operation on into the indefinite future, and the drive factor

there is the economics. That is, it can, I believe, be made less expensive to launch payloads in that several thousand pound category into synchronous orbit on the Delta, even at a modest launch rate, than to launch those same payloads on the space shuttle.

So the basic issue both in the Defense Department, I believe, and in the commercial sector and the competition with the Ariane launch vehicle in France, is a question of the cost of a space shuttle launch. It is imperative—and Defense has led the charge—in encouraging NASA to reduce the cost of operations of the space shuttle, to do everything possible to skinny that operation down to the point where the operation is highly economical and competitive with these 1960's technology expendable launch vehicles.

And until we are able to accomplish that I am afraid the expendables are going to continue to raise their ugly heads in relationship to the national policy of many years, over a decade, that we will phase those expendables out.

Senator GORTON. How many payloads a year is the Air Force going to launch that were previously scheduled for the shuttle?

Dr. COOPER. Well, the current plan is two—and the request for proposals from the commercial sector are planned for two a year for a period of 5 years. So the commitment essentially is to launch 10 payloads.

Senator GORTON. Is that a fairly firm number? Or could it go up on the basis of economics?

Dr. COOPER. I think that number is certainly a firm number in the request for proposal and to exceed that number probably would be difficult to accomplish because the liability that is going to be acquired by the Defense Department if we actually go ahead and execute this plan is a long-term liability for 10 vehicles only, and I would guess the changes to that plan would probably increase the expense disproportionately.

Dr. DELAUER. To make the problem more complicated than we would like, the Japanese have something called the N vehicle, which is a Thor-Delta, and they are looking at their next generation. They have got No. 4. And let me tell you, when you get the Japanese in competition with us on providing launch support activities as a way to promote that capability in Japan, we are in for a dogfight.

It is impossible, in my own view, for us to sit and think that we are the world of space and space vehicles and for us to establish a national policy that cannot be eroded or cannot be influenced by capabilities that exist around the free world. We just have not been doing our homework and finding out what the competition can really do.

And we transferred that technology to them. I can remember. I remember when we did it because the Thor-Delta was the Thor-Able. My laboratory built the Able vehicle, the first one. It was the first one that put one of the American satellites in orbit and became the Thor-Delta when NASA was formed. And I remember when we talked about transferring the booster technology to Japan, and they said well, it is OK, you know, it does not make any difference. They will not be able to do anything for 20 years.

The 20 years are up and we were right. They were not able to do anything for 20 years, but the 20 years are now up and they have

been able to do something with it. And it is a very integrated and complex question, and yet it is all going to ride on economics—pounds to orbit and which orbit you are talking about—dollars per pound.

As a matter of fact, my own view of it is we made a mistake on the shuttle pricing policy. It has changed the way that all the satellites were built. In order to quote the guy that was running it at the time, we cannot give all you satellite builders who are now building long, thin satellites that go on the Titans and Thors competitive advantage, so, therefore, we are going to price the shuttle payload requirements by the foot, and not by the weight.

And as a consequence we have redesigned all the satellites to be short and squatty, and as a result we eliminated a whole class of vehicle and shrouds that we could have used in the interim. And, thus, even this new vehicle, the biggest cost if we go ahead with this program is being able to get the shroud. It costs you $500 million to develop a shroud. It is a complicated business.

Senator GORTON. I understand that the Air Force is leaning toward using an Atlas-Centaur or a Titan-Centaur initially rather than a shuttle-derived launch vehicle. If so, what is more attractive about doing so and what considerations are being given to using the shuttle-derived launch vehicle as a heavy lift launch vehicle?

Dr. DELAUER. At the present time in the vernacular, there ain't no shuttle-derived launch vehicle. There have been concepts as ancient as 10 years ago. I think that what you are seeing now with the approval of the initiative both for defensive things as well as the space shuttle that all of a sudden NASA has now getting very much interested in doing something with a shuttle-derived launch vehicle.

I think we ought to work together and do that. But a shuttle-derived launch vehicle will not be a commercially attractive device, not in our lifetime, so that is why I am urging the Secretary to reexamine this whole question of starting off and guaranteeing, or at least underwriting, a commercially viable ELV program because it may not be one that fits in with the shuttle-derived.

We are going to need a shuttle-derived vehicle, but we are going to have to do something about that, too, because the shuttle subsystems are pretty expensive. There are probably other ways to have that class of vehicle where we could cut the cost down, so it is not just a question of band-aiding a bunch of shuttle subsystems together and assume that that is the most economic way to go. Those solids are expensive because of the manned requirement.

Senator GORTON. On the subject of the IUS failure in April 1983, your written testimony states that you are planning for an initial IUS flight capability this fall. When is that scheduled, and if you have not solved the IUS problem by the fall, how will this affect your shuttle missions for the next 2 or 3 years?

Dr. DELAUER. Let me get my crib notes and see how we are doing on it.

Dr. COOPER. I think, Mr. Chairman, the current plan is a December launch of a classified payload from the SAFSS office.

Dr. DELAUER. I think that is the one we are planning on and if we do not have that I think that we would have to wait and transition to the Centaur.

Senator GORTON. The Air Force has already postponed two dedicated shuttle missions, one last November and another for this next July. Do you expect to accommodate both of those postponed missions on your next shuttle mission?

Dr. DELAUER. I do not think so.

Dr. COOPER. One.

Dr. DELAUER. One, I think. The reason for the postponement was the fact that much of our schedule has to do with what you would call——

Senator GORTON. So one is all are going to need?

Dr. DELAUER. Right, for replacement.

Another thing, just for your information, it is now becoming obvious that we could use deactivated Titans for certain of our missions, particularly for GPS, and we are taking steps to salvage the deactivated Titans for GPS. But there again goes another way to handle a potential shuttle payload. But it looks like that probably will be the most economical way and the most flexible way to handle GPS replenishment.

Senator GORTON. According to your testimony, Doctor, as part of the strategic defense initiative your space power program could have applications for energy requirements of the proposed civilian space station. What other DOD technologies are being developed that might help in the development of that space station?

Dr. DELAUER. I think our work in lightweight space structures, our work in attitude control systems, and the algorithms and the software in our very high speed integrated circuity is important. In addition, the work that we started in DARPA, is what I would call a strategic computer program or supercomputer program. All are going to have applications to a space station in one form or another.

Senator GORTON. So we really are going to continue to get the benefits flowing in both directions?

Dr. DELAUER. No question about it, no question about it.

Dr. COOPER. Absolutely.

Senator GORTON. Even though DOD has not identified any military requirements which would be uniquely satisfied or significantly enhanced by a space station, we have heard that the Department might ultimately like to use the space station for some R&D activities.

Dr. DELAUER. That is right.

Senator GORTON. Could you speculate as to what type of activities DOD would be most likely to engage in initially and, being even more speculative, how you might use it by the year 2000?

Dr. COOPER. We have done a number of studies in the past to try and determine how military men in space could be used, and in almost every case no real operational imperative has been found for military man in space in a continuing space station-like environment. But it has always been recognized that doing experimentation in space is expensive in the extreme, with automated spacecraft.

A good example of that is the Teal Ruby experiment that I alluded to earlier, where we are building an autonomous spacecraft that will finally, excluding the launch costs, have an expense of around $500 million. It is quite possible, we think, to take experiments like

Teal Ruby, which is essentially a surveillance experiment using very advanced infrared technology, and do that kind of thing in a man-attended mode on the space station.

There are some benefits to that. There are some undesirable features to that kind of environment, but I think on balance the cost tradeoffs will be quite favorable in the final analysis, and that will be the kind of activity that Defense will be doing in the space station.

I might point out that our best intelligence estimates of what the Soviets have been using the Salyut space station for [deleted].

It is that kind of experimentation with man-tending which also might be beneficial to our programs for the future.

Senator GORTON. What impact on those programs will foreign participation at the level which is currently being discussed with respect to the space station have? Is that going to drive you out of these opportunities?

Dr. DELAUER. I do not think so. I think that the nature of some of the things we are going to be doing—and our foreign participation is mostly with our friends, we have yet to make an overture to the Soviets to send a few—that could possibly happen in the future, as it happened in the past once, is applicable to both the strategic defense initiatives as well as in the space station we have as part of our program the alliance participation. We want them to participate. You know, it is a big investment on our part. I would like to have somebody help us invest in the thing.

A lot of the technologies that will come out of the strategic defense initiatives have applicability to nonballistic missile defense activities; a lot of the command and control and surveillance are applicable to conventional weapons. So if we can get our allies to participate in those efforts at the R&D stage it will be an investment in the Alliance that has long-term security implications and we ought to encourage it.

I think in the case of NASA, they should speak for themselves, but I think there are two things—one, that we would like to have them participate because I think it would reduce our resources required, and second it also would provide us a source of talent that may not exist in this country or only exists in limited quantities.

So I think the positive parts of the cooperation much override what might be a certain negative part, and we will just have to work around it.

Senator GORTON. Your testimony indicates that our present space launch capabilities would be jeopardized if the U.S. homeland were under direct attack. In relation to this discussion, what would constitute a direct attack? To what extent would a direct attack on the United States affect in the near term our space launch capabilities?

Dr. DELAUER. Well, if we lose ground facilities, you know, school's over, and that direct attack could come by full-scale declaring of hostilities or it could come by terrorism. We have been very lucky in this country about the consequence of terrorism, but whether we are going to be that fortunate in the future is something we have to worry about.

Senator GORTON. Are you satisfied with the security measures which you have to protect against terrorism?

Dr. DeLAUER. No; we have got a major program going on in security measures and it is one that we are carrying out, not at the speed I would like, but it is a resource allocation problem. People would maybe rather have another wing of fighters instead of protecting the wings we have got. The whole security measures program is not just limited to space launch systems. On the other hand, our space launch systems, other than those at Vandenburg, you know, are in essentially an unprotected place.

Have you been down to the cape? You probably have been, I know you have, been to the cape. You know, that is a kind of a wide-open territory. Vandenburg has a little bit tighter security, but access from the sea is a cinch. And there is a question before the House and which we are looking at is how much we want to put in for protection or how much we want to put in to some other things.

It is the same problem. We have the same problem and, you know, we do a better job of protection of our nuclear assets.

Senator GORTON. On the same subject, you state that additional survivability options beyond an assured launch capability are being pursued to insure sustained operations of critical space assets after enemy attack. What kinds of options? How can they be implemented?

Dr. DeLAUER. Well, for instance, not much has been said about it, but certainly the ability of the MX to put payloads into orbit would be part of the MX program, as we get further down the stream. We are taking a look at some vehicles. They have been looking at launch vehicles that are more of the airplane type, but they still have the same problem.

It is a question, I think, of just preparing a contingency plan that permits us to have survivable launch capability. There is two things you can do. You could have survivable launch capability, which is what we refer to there in some way. The other is to make the space capsules more survivable, so that the requirement for timeliness of replenishment can be reduced, either by proliferation or by hiding or by some other ways to do things.

You can make the spacecraft itself more survivable, particularly our communications and our surveillance ones, and we are in the process of doing that.

Dr. COOPER. For the near term clearly, the easiest thing to get at is storing spacecraft on orbit, and a good example of that are the plans that we have in place now for the GPS navigation satellite system where we will have stored on orbit a number of spacecraft that will not be being used regularly but which could be pressed into service if those spacecraft somehow came under attack.

And in the [deleted] program, where we have similar plans for the long range for that program.

Senator GORTON. In your testimony you mentioned that you expect the Soviets to deploy their large permanently manned space station by the late 1980's. What does the term "large" mean in that respect, and how will the capabilities of this station compare with what we anticipate for our own?

Dr. COOPER. Well, we do not know how large the Soviet space station might be, but we have indicators of the scope or scale that such a station might have [deleted].

But if you look at the lifting capability of that launch system it probably lies somewhere in the range of [deleted] into low-Earth orbit. A station that size could have a life support system that could support [deleted] people, so perhaps somewhere between [deleted] people could be supported in orbit by life support systems within that weightlifting capability.

Senator GORTON. How does it compare and what do you feel its capabilities are likely to be compared to what we are attempting to design?

Dr. COOPER. Well, it is my understanding that NASA's preliminary designs are more in the [deleted] for the number of people supportable on a continuing basis by the life support systems they are planning.

Senator GORTON. What military implications does this large Soviet space station have?

Dr. COOPER. Well, since no operational need has ever been identified for our forces, particularly for such a large group of people in space, and since we have only seen the Soviets doing experiments in space, we can only conjecture about what operational need there might be, military need there might be, for such large numbers of people in space.

It is hard to say.

Senator GORTON. But it is not something that you are attempting immediately to counter by a similar capability?

Dr. DELAUER. No; we are not.

Senator GORTON. How vulnerable would the proposed U.S. space station be to an attack by a Soviet antisatellite interceptor and to what other types of attack might our proposed space station be vulnerable?

Dr. DELAUER. Well, to answer your first question, 100 percent. If they want to shoot it down, they can shoot it down. They have demonstrated the ability to do that. The other forms, well, the things we have looked at in the strategic defense initiatives, there are other means of being able to essentially intercept and disable a spacecraft and a space station is just a big spacecraft.

Dr. COOPER. I see one asymmetry that might lead you to some conjectures or conclusions about what the Soviets might do with this large contingent of folks in orbit might be derived from the problems that they have in building highly complex automated spacecraft. Their spacecraft by and large do not have the functionality that ours do, and it is largely because [deleted].

It is possible to have man-tending for many of the functions of spacecraft, and increase the reliability substantially. A good example of where they could have used a man in orbit is the problem that they have been experiencing with their RORSAT. The RORSAT has a control instability which we have been observing for quite a number of years now, and was ultimately the cause of the failure of the ocean reconnaissance satellite that reentered in Canada a number of years ago.

That is still a problem for the Soviets. They experienced it again last year. It was the reason why they scaled down their RORSAT efforts last year. If there were a man-tending of that kind of capability clearly that is the kind of thing that some human intervention can fix quickly in space, and I would suspect that it is perhaps

the tradeoff for them is to have man-tended systems, perhaps associated with a massive life support system in a space station where they might get the most benefit out of that kind of capability.

That is a lesser problem for us because we have found ways to control the complexity of the functionality that we place in space and we have been very successful with that, with very few failures of our systems.

Senator GORTON. Thank you. I have a number of other questions I got about half done, but we are due to start an open session at 10:30, so, Paul, unless you have some questions, we will submit those in writing.

Senator TRIBLE. No, Mr. Chairman.

Senator GORTON. We express our appreciation to both of you for coming and for your candid and helpful testimony.

Dr. DELAUER. I hope we helped.

[The statement and answers to questions of Senator Gorton follow:]

STATEMENT OF DR. RICHARD D. DELAUER, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING, DEPARTMENT OF DEFENSE

INTRODUCTION

Mr. Chairman and members of the subcommittee, I am pleased again this year to review the Department of Defense's programmatic relationships with NASA in space and aeronautics. I will highlight our activities that are complimentary and address specifically those programs in which we work jointly with the National Aeronautics and Space Administration. As I have done in the past and in keeping with the prior interests of this committee, I will begin by briefly describing recent Soviet activities in space to provide perspective for our program.

SOVIET SPACE ACTIVITIES

The expansion of Soviet space programs and capabilities continued unabated in 1983 [deleted]. Through the 1980's, we expect the Soviets to not only continue supporting their current large number of space programs, but to expand the scope and capability of these systems to directly and indirectly support Soviet land, sea, and air forces. On any given, day 95–115 Soviet satellites are in active use to support government and military forces. Development continued in 1983 on new capabilities: First, two new space boosters, one a heavy lift vehicle in the Saturn V class for large space station modules, and the other a Titan 34D class medium lift vehicle, possibly for rapid deployment of military satellites; second, reusable transport systems, one a U.S. shuttle type orbiter and the other a smaller space plane; and third, large permanently manned space station complexes. The heavy lift vehicle we project would be launched in the [deleted] time frame and be capable of lifting 220,000 to 330,000 pounds into low earth orbit. By comparison the U.S. space shuttle can lift approximately 65,000 pounds into low Earth orbit. This large booster could be used for placing large space stations in orbit, for supporting manned lunar and planetary exploration [deleted]. A variant of the vehicle will be used to launch their shuttle craft in the late 1980's, providing the Soviets with capabilities similar to those of our own space shuttle. [Deleted.] The Soviets have continued to expand their research, effort, development testing and evaluation facilities, production and manufacturing plants, launch facilities, and space mission control network to support this large space effort.

Soviet military space capabilities include an anti-satellite interceptor, operational since 1971 and effective against low altitude satellites [deleted]. A full array of [deleted] reconnaissance satellites [deleted]. A missile launch detection capability against U.S. ICBM fields and test facilities; an expanding communication satellite system [deleted] and several military satellite networks for navigation, meteorological, and weapons system R&D support. Perhaps the most unique feature of the Soviet programs, and one which has military potential, is their manned program. The program consists of a current operational space station, a future large permanently manned space station, and ferry spacecraft for cosmonauts and equipment to sustain long-term manned missions. The trends and momentum of the Soviet space

program for the past 16 years reflect a commitment to develop and deploy space capabilities that enhance and project military power. I will now discuss some selected highlights and noteworthy developments during 1983.

[Deleted.]

[Deleted] rorsat activity in 1983 was curtailed most likely due to problems that occurred with cosmos 1402, the last rorsat launched in 1982. This problem was reminiscent of the 1978 cosmos 954 incident when it failed to boost its nuclear reactor into high storage orbit at the end of its mission. After the 954 malfunction, two years elapsed before the Soviets launched their next rorsat [deleted].

The large and extensive [deleted].

The second manned flight for Salyut-7 was performed during 1983. Soyuz T-9 cosmonauts, V. Lyakhov and A. Aleksandrov, successfully completed a flight of 149 days on-board the space station complex. [Deleted.]

[Deleted.]

[Deleted] the Soviets performed a variety of military related experiments and operations, gaining considerable experience and knowledge for the eventual operation of their large permanently manned space station projected for the late 1980's. [Deleted.] Another first in Soviet manned flight was the manning of a cosmos 929 type space station module (cosmos 1443). The cosmos 1443 module carried approximately 3000 kg of supplies and equipment to Salyut-7 and returned [deleted] other equipment to Earth. This vehicle has been announced as a multi-purpose vehicle capable of being used as a tug, module, free-flying spacecraft or resupply vehicle. [Deleted.]

[Deleted.]

DOD SPACE ACTIVITIES

To maintain the security of the United States, the Department of Defense acquires and operates space systems and pursues advances in related research and technology development. During the past year, we have moved further down the road in accomplishing the goals of the DOD space policy.

To continue the momentum of achieving technically superior systems with enhanced operational characteristics, we are requesting 12.9 billion dollars for Department of Defense space programs in FY85. This represents an increase of 22 percent (real year dollars) over the corresponding 10.6 billion dollars appropriated in FY84.

In my testimony last year, I discussed the Air Force's consolidation of space operations and advocacy through formation of the space command. During the past year, additional activities within the Department of Defense have further consolidated space activities. The Department of the Navy on October 1, 1983, established and Navy Space Command, headquarters at the Naval Surface Weapons Center at Dahlgren, Virginia. This command headed by former astronaut, Commodore Dick Truly, assumed operational responsibility for Navy space systems, plus coordination responsibility with other operational activities. Two of its major operational responsibilities are they Navy naviation satellite system, commonly referred to as transit and the naval space surveillance system or NAVSPASUR. In October of this year, this command will expand its responsibility to include Navy satellite communication, including GAPFILLER, FLTSATCOM, and LEASAT satellites.

To enhance joint planning for space systems supporting the commanders of the unified and specified commands and to develop the transition plan for a new unified command, the JCS, on February 1, 1984, established a joint planning staff for space [JPSS]. The JPSS will coordinate development of concepts, requirements and plans for military exploitation of space, analyze the responsiveness of space systems to NCA and JCS direction, and evaluate the mission support provided to the CINCS by space systems.]

As you are aware, the DOD is pursuing the development of an operational antisatellite [ASAT] capability. This capability is needed, first and foremost, to deny the Soviets the use of those space systems that directly threaten U.S. and allied land, sea and aerospace forces. An operational U.S. ASAT will also deny the Soviets the sanctuary they currently enjoy in space and will deter Soviet ASAT attacks on our satellites. The baseline air-launched miniature vehicle [MV] ASAT is currently in test and will satisfy the performance objectives established in 1979. [Deleted.] First flight test occurred on January 21st of this year and demonstrated booster performance and guidance. The second flight test, scheduled for [deleted] will include the MV, and use a star for sensor calibration.

I would now like to focus on development, operation, and future plans for space transportation and related space activities of joint NASA/DOD interest.

Let me begin by addressing the subject of defense space launch strategy. On July 4, 1982, the President signed a "national space policy" which stated, "the U.S. space

transportation system [STS] is the primary space launch system for both national security and civil government missions." The DOD has been and remains committed to the space shuttle as our primary space launch system. Virtually all national security payloads are being modified or have plans to be modified to fly on the shuttle. However, the President's directive also recognized that national security considerations may dictate development of launch capabilities other than the space shuttle so that we have an assured access to space.

This requirement for an assured access to space exists not only under peacetime scenarios, but also under crisis and conflict conditions. Assured access to space is a function of satisfying two specific requirements—the need for complementary systems to hedge against the need for demand launches to replace unanticipated failures of critical space assets to provide insurance in the event unforeseen technical and operational problems and the need for a system suited for operations in crisis and conflict situations. While DOD policy requires assured access to space across the spectrum of conflict, the ability to satisfy this requirement is currently not achievable if the U.S. mainland is subjected to direct attack. Therefore, our near-term launch strategy addresses an assured launch capability only through levels of conflict in which it is postulated that the U.S. homeland is not under direct attack. Additional survivability options other than an assured launch capability are being pursued to ensure sustained operations of critical space assets after enemy attack.

Existing defense space launch planning specified that DOD rely on four unique, manned orbiters for primary access to space for all national security space systems. DOD is concerned that this, coupled with an eroding industrial base, may not represent an assured, flexible and responsive access to space. The Defense Department believes that total reliance upon the STS for access to space represents an unacceptable national security risk. DOD believes that a complementary system is necessary to provide high confidence of access to space.

The solution to the problem must be affordable and effective, while offering a high degree of requirements satisfaction, low technical risk, and reasonable schedule availability. An unmanned, expendable launch vehicle meets these criteria and could satisfy DOD operational needs for a launch system which complements the STS and extends our ability to conduct launch operations further into the spectrum of conflict. These systems can provide unique and assured launch capabilities in peace, crisis and conflict levels short of general nuclear war. These vehicles are designed to be expendable and the loss of a single vehicle affects only that one mission and would not degrade future common, national launch capabilities as would the loss of a reuseable launch system.

At issue here is the realization that we as a nation are losing our launch vehicle industrial base, both in shuttle and ELV's. At this point there are no new contracts being awarded for procurement of space launch systems. The last shuttle orbiter will be delivered this year and the last Titan is almost completed. As a result, the U.S. will soon be totally reliant on four orbiters for providing access to space. Furthermore, unless we take action quickly, the Nation's industrial base for space launch vehicles will quickly erode.

On February 7th, the Secretary of Defense promulgated his space launch strategy in response to validated DOD assured space launch requirements and implemented the launch policies contained in the national space policy and the defense space policy. This strategy addresses both the near and long term. In the near term the STS will remain the primary launch system for routine DOD launch services. Unmanned, expendable launch vehicles represent a complementary capability to the STS and will be maintained and routinely launched to ensure their operational viability. To accomplish this, selected national security payloads will be identified for dedicated launch on ELV's, but will remain compatible with the STS. In the long term we must ensure that future national security space missions are not constrained by inadequate launch capability. Therefore, the need for other DOD launch capabilities to meet requirements beyond the early 1990's must be evaluated and validated. This evaluation naturally will examine such things as the need for a heavy lift vehicle.

Let me add that although we are pursuing a limited ELV capability to complement the shuttle, and we continue to study the ELV question, the DOD remains fully committed to the shuttle. We have invested far too much time and money to ensure that we have not created a "dinosaur" and believe me it will take more than an ice age type occurrence to kill off the shuttle species. One needs only to look at the DOD investment in shuttle development, the costs of the Vandenberg launch facility and the size of the program concerned with the CSOC to gauge how much the shuttle means to DOD. What we are addressing with this space launch strategy is not the determination of a good versus bad or adequate versus an inadequate

launch system but a national security need that cannot be compromised. The ELV question is one part of the overall strategy, and we will continue to investigate alternatives including those that take advantage of our investment in shuttle technology, and in the end decide on a course of action that is the most cost effective to the nation and at the same time guarantees our assured capability to perform space operations.

With regard to the 5th orbiter question, I have the following comments. A four orbiter fleet with all orbiters in service would support 17 to 25 flights per year which approximates NASA's projected mission model. What concerns me is that given our reliance on the shuttle, and recognizing that everything has a finite life, it is important that we plan on how to maintain this shuttle capability. Regardless of assumptions, a four orbiter fleet cannot tolerate attrition or extended down time either for overhaul or repair without significant impact to the user community. As I have testified in the past, the DOD does not have an explicit requirement for a 5th orbiter since we have the option of bumping payloads for national security use of the system. The question of the 5th orbiter should not rely on an explicit DOD or civil requirement but on the issue of maintianing the shuttle program.

STRATEGIC DEFENSE INITIATIVE

Mr. Chairman, for the past three years, this administration has sought to restore the balance of forces necessary to maintian peace and stability by modernization the strategic deterrent while at the same time pressing for significant, verifiable arms reductions. This year, the President has included in the defense budget a research program that explores the possiblity of strengthening deterrence further by taking advantage of recent advances in technology that could, in the long term, provide an effective defense against ballistic missiles. The new program focuses on existing research and development programs, totaling nearly $1.8 billion (88 percent DOD, 12 percent DOE) in FY 1985, in five technology areas that offer the greatest promise for defense against ballistic missiles. It also includes an additional funding increment of about $250 million to augment these and exploit other new technological opportunities.

In consolidating these efforts, the strategic defense initiative seeks to develop sund technical options that could allow future Presidents to decide whether to develop an effective defense against ballistic missiles. While such a research effort would not affect current arms control treaties, the President also directed a full and continuing assessment of the future implications of developing strategic defenses for our defense posture, detrrence strategy, and arms reduction program.

The strategic defense initiative is designed to work toward the long term national goal, set by President Reagan in a speech to the American people las March, of putting an end to the threat of ballistic missiles. To determine the technical feasibility and strategic implications of pursing that goal, the Defense Department formed two study groups of scientisits and national security experts. The reports of those studies, submitted in October 1983, form the basis for the proposed strategic defense program. The defensive technologies study, headed by Dr. James Fletcher, the former Director of Nasa, concluded that promising new technologies are becoming available that justify a long term research effort to identify future technical options concerning the development of a defense against ballistic missiles. Exploring the implications of strategic defense, two future security strategy studies, one interagency and one contractor, concluded that defensive systems could strengthen stability and deterrence and enhance prospects for arms reduction.

The studies recognized that there are uncertainties that will not be resolved until more is known about the technical characteristics and capabilities of defenseive systems and the response of the Soviet Union to U.S. initiatives. The uncertainities notwithstanding, the studies concluded that it was essential that options for the deployment of advanced ballistic missile defense be established and maintained. Our national security requirements permit us no alternative because the decision to begin ballisticmissile defense deploment is not solely a U.S. decision. For a numbr of years the Soviet Union has pursued advanced ballistic missile defense technologies, and it is the only maintaining an operational system of terminal ballistic missile defense. Unilateral Soviet Deployment of an advanced system capable of effectively countering western ballistic missiles—added to the already impressive Soviet air and passive defense capabilities—would jeopardize deterrence because the United States would no longer be able to pose a credible threat of retaliation.

In the 1980's, technology has progressed to the point where a focused research program for developing effective defensive systems is a feasible proposition. For example, one of the fundamental ingredients in a strategic defense system is the abili-

ty to make millions of logical decisions per second. Recent advancements in data processing capability make possible for the first time the real time surveillance, acquisition and tracking of large numbers of strategic missiles and warheads. Miniaturized data processing capabilities also provide for basing options that were inconceivable a decade ago. Recent progress in directed energy technologies, more sophisticated sensors and enhanced survivability, when added to our computing capability, now allow us to think about a research program with real potential for answering the technical questions that are crucial to an effective strategic defense capability.

In spite of these encouraging developments, we want to emphasize that the strategic defense initiative is not a weapons system development and deployment program, but rather a broadbased, centrally managed research effort to identify and develop the key technologies necessary for an effective strategic defense. The research will be initially focused on: Technologies for sensing and tracking missiles; technologies for weapons to be used against missiles and warheads; technological support for control of such a system; and technologies to ensure the survivability of the system. The specific research efforts will be organized in five areas: Surveillance, acquisition, tracking, and kill assessment; Directed energy technologies; kinetic energy technologies; systems concepts, battle management, and command, control and communication; and survivability, weapons lethality, and support systems.

It is highly unlikely that our research efforts would lead to a single system that could intercept and defend flawlessly against all missiles and all attacks. There is probably no such "magic bullet." What we anticipate is a defense network, a series of systems not necessarily based on the same technology or physical principles, which taken together will provide an effective defense against ballistic missiles. Such a set of systems will almost surely be layered—that is, designed to cover the full trajectory of a ballistic missile. This layered system offers the potential for a highly effective defense of the United States and allied countries. Obviously, our research effort must overcome numerous complex technical challenges. By our beginning a broad-based research effort now, future Presidents and future Congresses will have the option of deciding whether to proceed with the actual development of the most promising strategic defense systems.

In proposing that we begin a research effort to develop defensive technologies, the President is hoping to develop a means of maintaining peace, in addition to offensive strategic forces and arms reduction, that could provide a stable and secure environment for our Nation and our allies in the next century. Strategic defense, when combined with stabilizing offensive force modernization and mutual overall nuclear arms reductions, holds the promise of substantially lowering the utility of ballistic missiles. This initiative will provide future Presidents important tools and options with which to stabilize future crises.

While moving to explore strategic defenses, the President remains fully committed to force modernization and arms reduction. To maintain an effective deterrent now and in the years ahead, we are continuing the effort to modernize our strategic and intermidiate-range nuclear assets and conventional forces. To move toward genuine and significant arms control, the President is pursuing a series of ambitious arms reduction proposals. In fact, arms reduction and defensive force options can be mutually reinforcing. Effective, advanced defenses that reduce the utility of offensive nuclear arms have the potential for increasing the likehood of negotiated reductions of those offensive forces. In turn, effective limitations on offensive systems can be important in assisting defensive systems to reach their full potential.

While remaining consistent with our dual policies of deterrence and arms reductions, the strategic defense initiative must also complement other elements of our national security capabilities and policies. Considerations of defenses against a range of nuclear threats does not diminish the need to strengthen U.S. and allied conventional military capabilities to maintain our commitments around the world.

An effective defense against ballistic missiles can have far reaching implications of enhanced deterrence, greater stability, and improved opportunities for arms control. Our efforts do not seek to replace our proven policies for maintaining peace, but to strengthen their effectiveness in the face of a growing Soviet threat.

A hallmark of the strategic defense initiative [SDI] is to reserve up to five percent of the SDI resources for innovative approached and technologies relevant to ballistic missile defense. Just as the technologies which make ballistic missile defense feasible are only recently emerged, some of the technologies which may be ultimately incorporated in a defensive system are likely not yet identified. Following the President's challenge to the scientific community "to turn their great talents to the cause of mankind and world peace, to give us the means of rendering these nuclear weapons impotent and obsolete," The SDI has been formulated to provide the maximum accessibility and participation of the civilian scientific community. One important

aspect of this objective is to seek close working relationships with NASA and the civilian space science community.

Since the SDI is a research and technology program, many of its products will pursue technologies relevant to the civilian space program. For example, the SDI plans to develop advanced infrared detectors, large lightweight optics, "gig-up" computer processors, and new imaging technologies. All of these are space applications programs. We plan to coordinate our programs closely with NASA to ensure maximum utility to the overall U.S. space effort.

For some longer term U.S. space requirements, the SDI plans to jointly sponsoring high priority research programs with other government agencies. Two particular joint programs have already been identified. When the planners of SDI looked at the space system concepts and technologies being considered, they realized that they would require electrical power levels far in excess of that available from current space power technologies. The space power program as defined by the DOD will work in two different regimes. The first is development of technology for survivable, continuous operation space nuclear power systems in the 10 to 1000 kw range. This is expected to grow to a few megawatts of continuous power for some of the SDI applications. The second is a long range research program to provide much higher power levels—perhaps hundreds of megawatts—for short bursts of hundreds of seconds. The space power program is considering both nuclear and non-nuclear alternatives for the multi-megawatt burst aspect of the program.

Applications for the 100 KW class (10–1000 KW, continuous) program are relatively near term. I feel that the first applications of space nuclear power in the 100 KW class will lie in three broad areas. The first would be communication satellites for both military and commercial use. Space nuclear power could provide very survivable satellites with enormous data capacity and flexibility even in the face of a hostile, jamming environment. The second application would be advanced, high power radar satellites, principally for the shuttle military applications but with some secondary civil uses such as air traffic control and global weather monitoring and forecasting. The final area involves growth versions of NASA's space station which will require increasing power levels for manufacturing. There is a wide range of additional applications including space surveillance, tracking, designation, cryogenic support, and so on for both SDI and other military uses. Additional civil uses would include electric-propelled space "TUGS" and outer planetary exploration, Nonetheless, we expect that the communication, radar, and space station applications will be the first applications and will serve to focus the technology program. We will select 100 KW class system concept and demonstrate technical and safety feasibility in time for initiation of a development and gound test program starting in FY86. First space application flights could be supported in the early to mid-1990's. NASA and the Department of Energy are providing substantial funding for this part of the program in FY85 as they have in the previous two years.

For the multi-megawatt, burst mode space power systems, the applications principally involve future space weapons as part of the strategic defense initiative. Since the applications are much more distant than for the 100 KW class, we are structuring a long range research program. We do not expect to select a specific system for development until 1990 or 1991 at the earliest. Until that time, we will be developing those nuclear and non-nuclear technologies leading to potential order-of-magnitude increase in power and run time and a similar reduction in system mass and cost. Technology research will be conducted in high temperature materials, energy storage, reactor techniology, lightweight MHD and turbogenerator energy convertors, and ultralightweight space radiators for excess heat. This research program is being planned now for a start in FY85.

To provide continuity and close coordination of the multi-megawatt program with the ongoing work in the 100 to 1000 KW range, we have given the charter for all technology and concept development for medium and high levels of space power to the SP-100 organization. You may recall that the SP-100 organization was formed by agreement between the Department of Energy, NASA, and DARPA in February 1983. By having the SP-100 organization direct all aspects of the space power technology program in response to guidance and direction from the SDI program director, we will ensure effective coordination with NASA and DOE as well as guarantee that non-SDI defense and civil applications are also fully supported. Many of the advanced space systems being considered for strategic defense, both surveillance and weapons components, require electrical power levels three or four orders of magnitude above current capabilities. We have asked the Naional Academy of Science to conduct a study of the technical options available to reach these power levels. We are sponsoring, with NASA and the Department of Energy, efforts designed to provide spacepower levels from hundreds of kilowatts to hundreds of megawatts. The

defensive technologies study (Fletcher study) also identified the long term requirement for large quantities of mass in orbit both to be used as shielding and for construction. We are exploring with NASA the possibility of using near-Earth resources (lunar or asteroidal material) for these purposes. Other long term requirements in space logistics, such as heavy lift and orbital transfer vehicles, are likely programs for close coordination among the various U.S. space efforts.

I would now like to bring this committee up-to-date on a number of programs that not only reflect the close working relationship of the NASA and DOD but also are of interest to the committee.

We are continuing with the development of the Consolidated Space Operations Center or CSOC and the Vandenberg facility. Regarding CSOC, we have awarded the contract to provide system integration support services. Facility design and site preparation work are complete and the contract for facility construction has been awarded. The design of the satellite control information processing system is proceeding with more than 30 percent of the software completed. We are scheduled to begin operation in early 1986 with a satellite emergency backup capability and plan to have a shuttle planning capability in the late 1980's. Recently there has been some question as to the need for operations and planning center or SOPC portion of the CSOC. I would like to dispell these questions once and for all. This facility will provide redundancy for the JSC facilities, enhance security, and permit more DOD autonomy. This autonomy is an important factor since it offloads NASA and JSC facilities and personnel, thereby allowing NASA to concentrate more resources on new initiatives such as space station. Additionally, the SOPC would provide an avenue for force structure integration for programs such as SDI with a unified space command, and function as a node in the overall military command system. Furthermore, the establishment of SOPC enhances the "separateness" of the civil and military space activities.

The Vandenberg AFB ground system construction, equipment installation, and checkout continue toward the October 1985 first launch. The launch processing construction which includes the launch control center, launch pad, external tank processing and storage facility, solid rocket booster processing facilities, and orbiter checkout and maintenance facilities is 95 percent complete. Ground system testing to checkout facility equipment is scheduled to begin in May. Flight hardware compatibility tests using enterprise will begin in November. The actual flight orbiter—discovery—will arrive in May 1985. Vandenberg is designed to support three launches in FY86 and four launches per year thereafter. For the FY86 launches, NASA will process and checkout the orbiters and external tanks at Kennedy Space Center. After FY86, those functions will transfer to Vandenberg for West coast launches.

The IUS failure that caused the second stage motor anomaly during STS–6 has been identified. The interface between the motor and the exit cone that enabled the nozzle to gimbal, the tech roll seal, failed approximately 83 seconds into the 127 second burn. Design modifications are in work. We are planning for a flight capability late this year. Related to the IUS problem is the recent notification on February 6th by the Secretary of the Air Force that the IUS would exceed its baseline unit cost by more than 25 percent. Of this 25 percent increase approximately 8 percent can be attributed to the IUS anomaly. The primary cause of the unit price increase is the quantity reduction from 18 to 10 caused by the transition to centaur of milstar and outyear DSCS and DSP.

The centaur is a high performance cryogenic upper stage being developed jointly by NASA and the Air Force. There are two versions: The G prime for NASA interplanetary missions is the same basic design as centaurs flown on the atlas and will deliver approximately 10,000 pound payloads to geosynchronous orbit. The G version is for DOD missions. It is a shorter version than the G prime thus allowing for larger volume payloads in the shuttle cargo bay, and will provide 10,000 pounds to geosynchronous orbit. The Joint program office is at NASA's Lewis Research Center. The first launch is scheduled for May 1986 on a Galileo Planetary mission. The first DOD capability will be in the fall of 1987. Our cost is in line with our original estimate, with the Air Force share of the development costs less than $150M.

The Navy remote ocean sensing system or N-Ross is an excellent example of interagency participation. As envisioned, the Navy, in conjunction with NASA, the Air Force and NOAA, will work to provide a military and civil capability for obtaining data on sea surface temperature and precipitation, sea surface winds and waves, ocean fronts and eddies, and ice edges and extent. I might add that DOD and NASA are proceeding on schedule and we in DOD are supportive of the full NOAA participation in this program. I have recently sent a letter to OMB urging the transfer of a

spare weather spacecraft from NOAA so that the program can get back on track for a 1989 launch. Without NOAA participation, the total government cost will increase $30 to $50 million and delay the launch to 1990. I would solicit your support in resolving this issue since N-Ross will benefit all military, civil, and commercial users.

With regard to the space station, I would point out that we have been working with NASA on their space station concept for over a year, as well as performing internal Air Force and DOD studies in an attempt to identify unique military requirements. Our efforts to date have not identified military requirements that would be uniquely satisfied or significantly enhanced by a civil space station. Now that the President has chosen to initiate a space station program, we will certainly continue our studies and examine potential capabiiities wherein the space station can satisfy future requirements. In any event, the Defense Department has appropriate representation on the NASA space station task force and will work closely with NASA to assure that we are well informed on the progress of the program.

Mr. Chairman, I would now like to discuss the status of the Darpa Laser Triad program since it is one of the major parts of the overall strategic defense initiative program. The Talon Gold space experiment to establish the technical feasibility of acquisition, tracking, and pointing [ATP] completed its interim design review during 1983.

[Deleted.]

The Alpha program or high power chemical laser ground-based experiment completed the design of the Alpha 1 ground based demonstration laser this past year.

[Deleted.]

The large optics demonstration experiment or lode is the third part of the triad program which will demonstrate the critical beam control and optics technology in a series of ground-based experiments that simulate the space environment. Following a preliminary design review [PDR] of two competing mirror designs and an evaluation of supporting mirror brassboard results, a single source was selected for the final design of the hardware and manufacturing support equipment for the "lode advanced mirror program [lamp]". Long-lead procurement of materials and glass faceplates for the mirror segments was initiated and intensive design activities led to successful PDRS of key subsystems at the end of FY 1983. The design of the lode brassboard, to be used to verify lode design concepts and hardware trades, was completed and all key hardware items were ordered. Significant changes in content, but not objective, have been made in the lode program to provide more responsivenes to high-brightness weapon concept technology requirements. These changes include (1) using a simplified but more scalable beam expander, (2) introducing increasing complexity of the experiment in a stepwise fashion in order to isolate the effects of nonlinear control phenomena and structural interactions, (3) testing the beam control system fully at subscale before incorporating the [deleted] lamp mirror, and (4) testing the [deleted] lamp mirror in the auto collimated mode. These changes have resulted in an accelerated schedule and reduced technical risk for the overall program. The brassboard will be assembled and checked out in FY 1984 and the results will be used to verify the basic lode design concepts and provide data to support the final CDRS that will start at the end of FY 1984. The lamp mirror design is being completed and CDRS of major subsystems will be held throughout the year. Several breadboard activities are supporting the CDR efforts: The fabrication breadboard demonstrates, at subscale, the techniques for polishing the large, complex glass panels; another breadboard proves the design and performance of the mirror panel steering actuators; and a final breadboard demonstrates the active figure control of a simulated mirror panel. Mirror facesheet blanks, key manufacturing tooling, and major test items have been delivered and processed to support the start of mirror facesheet grinding and polishing in 1984. [Deleted.] The entire triad program starting in FY 85 continues as part of the President's initiative on strategic defense.

The Teal Ruby program is a space-based experiment to evaluate infrared [IR] surveillance for the detection of aircraft targets against the Earth's clutter background. The Teal Ruby experiment represents the first large-scale implementation of a two-dimensional staring mosaic IR detector array and will also use the lightweight techniques developed in the halo technology program for design and manufacture of the teal ruby telescope. It is scheduled for shuttle lauch and will operate in space for a minimum of one year as the primary payload of the Air Force space test program satellite P80-1. In FY 1985, the acceptance testing of the Teal Ruby flight sensor will be completed and the qualification sensor removed from the spacecraft and replaced with the flight sensor for the final integration testing. Rehearsal will be conducted for planned missions and detailed experiment planning will also be conducted.

AERONAUTICS

Mr. Chairman, I would now like to review some of our key activities in the area of aeronautics technology. For FY 1985, the Department of Defense research, development, test and evaluation budget for aircraft and related equipment is 4.7 billion dollars. Of the amount, approximately 440 million is devoted to aeronautics technology development, which is that portion of our program most closely aligned to NASA activities. This year, we will see the culmination of several of our major aeronautical technology programs, with many of our large scale demonstration projects entering the flight test phase. My comments today will focus on these programs as this is the area where we are making the most measureable and dramatic progress; however, the subcommittee should be aware that we also maintain a significant broadbase activity aimed at developing the technology for longer term applications.

One of these areas which I believe the subcommittee should be aware of is our growing activities in what are now becoming known as trans atmospheric vehicles [TAV]. From our perspective, TAV's include manned or unmanned craft which might be single-stage-to-orbit or boost glide vehicles. In cooperation with NASA, we have developed hypersonic configurations—that is, those flying at speeds from reentry velocities down to mach 3 or 4—which result in double the range of a ballistic shape for the same weight. In addition, the resulting ten to one hundred fold increase in footprint landing area will yield the operational flexibility needed by military systems. We are gaining considerable knowledge in this area from shuttle operations, and we will certainly continue to work with NASA as we press forward in development of TAV technology.

A major focus of our aeronautics technology program continues to be on increasing the combat capability of tactical aircraft through the development of advanced flight control concepts. Our major effort in this area is our advanced fighter technology integration [AFTI] program. The AFTI effort is conducted on two test bed aircraft. The first is a specially modified F-16. This aircraft incorporates a tri-plex digital flight control system—with no mechanical backup—and additional control surfaces which provide the capability to execute decoupled modes of motion—pure rotation or pure translation about any axis—and the ability to demonstrate task tailored handling qualities for enhanced operational effectiveness. The phase I flight tests of the AFTI/F-16 were completed early this year resulting in the attainment of several technological milestones. Most notable of these are: established the military practicality of triplex digital flight control technology; validated credible design alternatives for reduced life cycle costs; demonstrated task tailored flying qualities which resulted in quicker and more accurate target acquisition; and established the feasibility of using voice command for secondary control activities.

The second phase of the AFTI/F-16 program will feature integrated flight control and fire control systems and be devoted to exploring and demonstrating advanced concepts in automated maneuvering attack in both air-to-air enagements and in air-to-surface missions, to increase effectiveness and reduce aircraft vulnerability.

The second aircraft in the AFTI program is an F-111 test bed modified to incorporate a smooth contour variable camber wing, known as the mission adaptive wing [MAW]. MAW technology promises the potential for a 25 percent improvement in fuel economy; 20 percent enhancement in maneuverability, and improved gust alleviation characteristics compared with the baseline F-111A. Flight tests of the MAW utilizing manual control of the wing contour will start in the second half of FY 1984, and demonstration of the wing camber under full automatic control, will occur in FY 1985. Both AFTI flight demonstration programs are conducted jointly with the NASA dryden test activity at Edwards AFB.

The Defense Advanced Research Projects Agency X-29, advanced technology demonstrator aircraft, is currently undergoing extensive ground testing in preparation for first flight in late 1984. The X-29 will demonstrate advanced aerodynamics, structures and flight control concepts and develop the technical data base and confidence to incorporate these concepts in future aircraft developments. The X-29 features a forward swept wing, highly relaxed static stability, three surfaces for pitch control, full authority canard aerodynamics, a new variable camber system, aeroelastically tailored composite wing structure, and an advanced digital flight control system that has no mechanical backup. The payoffs will include improved aerodynamic efficiency that will result in reduced takeoff gross weight and improved range/payload performance; inherent low speed and high angle of attack maneuver capability that can be exploited to decrease takeoff and landing distances as well as increase spin resistance; and the ability to reduce the time, risk and cost of future developments based on lessons learned integrating the X-29 high task technologies. In addition, it is anticipated that the flight test results will validate novel design

approaches which will provide new configurational options to address future mission requirements. The X-29 will complete a concept demonstration flight test conducted by an integrated NASA, Air Force, Navy and contractor team, and it is expected that this experimental aircraft will continue to be used as a test bed for future technology demonstrations.

Last year I reported that we were initiating a program to demonstrate the technologies required to attain short takeoff and landing capability in future fighter aircraft. This activity stems from concern regarding the survivability and sustainability of our land based fixed wing tactical aircraft in light of significant increases in threat capability. The Soviets have substantially increased the range and payload of their forward based aviation assets, thereby placing our tactical fields in jeopardy. In response to the growing threat, we will have to provide improved takeoff and landing capability in the next generation fighter. In order to insure that full scale development of this aircraft can proceed with acceptable risk in the 1989 time frame, we have initiated a short takeoff and landing [STOL] technology demonstrator program. This program will involve modification of an existing aircraft—F-15, F-16 and F-18 are all being considered—investigate several concepts to reduce takeoff and landing distances. These include: thrust vectoring and reversing nozzles; integrated propulsion and flight control; advanced high lift devices; and, soft/rough field landing gear. This effort is currently in the source selection phase, with contract award anticipated in a month or so. First flight of the STOL demonstrator is scheduled for 1987, with completion of the program in 1989.

We are very proud of our past accomplishments in advanced rotorcraft concepts and we continue to see significant payoff from continued investment in this area. The most recent notable success is the transition of the XV-15 tilt rotor research aircraft technology into the Navy/Bell/Vertol JVX aircraft. This aircraft, which is scheduled to enter engineering development in fiscal year 1985, is designed to provide the Navy, Marines, Air Force and Army with a self-deployable multi-mission vertical takeoff and landing capability. The JVX represents an excellent example of the application of technology jointly developed by NASA and the DOD, to provide increased capability to the operating forces.

Today in a similar manner, we are vigorously pursuing development of X-wing and convertible engine technology with joint NASA/DARPA programs. The X-wing is a stopped rotor VTOL aircraft, with transonic speed potential, which builds on the circulation control aerodynamics technology base developed by the Navy over the last decade. The program is currently in the detail design phase at Sikorsky with extensive subscale validation and risk reduction tests ongoing at Sikorsky, NASA and David Taylor Naval Ship, Research and Development Center [DTNSRDC]. The X-wing rotor-wing and its control system will be tested on the NASA/Army rotor systems research aircraft [RSRA] in 1985.

Objectives of the X-wing program include development of technology and acquisition of a data base sufficient to design a full scale aircraft and its control system. The flight program will focus heavily on the envelope expansion required for the inflight conversion of the rotor from the rotary mode to fixed wing flight and reverse. In the convertible engine program we are currently testing a new concept of variable geometry engine, capable of producing arbitrary combinations of thrust and torque. This technology involves innovative approaches to engine geometry, air flow management and digital control laws. Potential applications include the X-wing and other advanced VTOL aircraft, compound helicopters and large on-board power generation capability (over 5 megawatts) for advanced aircraft weapons

FY 1985 will see the culmination of our efforts to develop the advanced digital/optical flight control system [ADOCS], with flight test of the concept in a modified UH-60 blackhawk helicopter. The ADOCS is oriented toward increasing helicopter survivability through redundancy and exploiting the invulnerability of fiber optic data transmission to battlefield electromagnetic interference. This "fly-by-light" concept also promises improved handling qualities and reduced pilot workload as added benefits of the technology.

In a joint program with NASA, the Army has initiated development of advanced rotor systems technology. The thrust of this program is to capitalize on the integration of recent advances in rotor design, aerodynamics, structures and materials technology. Using the UH-60 blackhawk as a baseline, a few of the benefits which will be demonstrated include: 25 percent increase in hover out-of-ground effect [HOGE] altitude (approximately 1,000 feet); six percent increase in range; 18 percent improvement in productivity; and, a potential 60 percent reduction in parts count resulting in substantial improvements in reliability and maintainability. Two rotor systems will be fabricated; one to fly on a dedicated test bed aircraft to fully investigate the performance and operational improvements. The second will be fitted to

the rotor systems research aircraft in order to fully explore and document the advanced technology. The flight test phase is anticipated to begin in mid-FY 1987.

The Army is also pursuing the advanced composite airframe program [ACAP], which will demonstrate that compositie materials technology can be applied to primary rotorcraft structures to achieve anticipated cost and weight savings of 22 and 24 percent, respectively. In addition, ACAP will demonstrate reduced maintenance requirements, improved survivability, increased ballistic damage tolerance, reduced radar cross-section, improved crash worthiness and easier repair of battle damage. Bell Helicopter Textron and Sikorsky Aircraft are each developing flight demonstrator aircraft, with flight testing anticipated to start in mid-FY 1985.

We continue to make significant progress in improving propulsion system performance while striving to reduce development risk and costs, maintenance costs, and acquisition costs for a broad spectrum of aircraft applications. We have previously reported on a large fighter engine technology demonstrator with the potential for a 15 percent increase in thrust to weight ratio, a 15 percent reduction in fuel consumption and a 24 percent reduction in the number of parts as compared to the F-100 engine. We have now completed over 180 hours of cyclic testing on an improved core for this variable bypass ratio configuration which offers greater performance improvements. In the core of a competitive configuration, we have demonstrated the potential for a 20 to 25 percent increase in thrust/weight ratio, a 7 percent decrease in fuel consumption and a 60 percent reduction in the number of parts compared to the F-100. This core has completed 80 hours of performance testing, and we have begun testing in the full engine configuration. In FY 1985 and FY 1986, we plan to demonstrate these improvements in full engine configurations and continue our assessments of durability to ensure technology readiness for transition to the joint advanced fighter engine [JAFE] for the next-generation tactical fighter aircraft, and other suitable applications.

The primary goal of our modern technology demonstrator engine [MTDE] program is to demonstrate in a 6,000-horsepower-class engine configuration a 20 to 30 percent reduction in specific fuel consumption compared to existing engines in this class (T55, T56, T64). We also expect to demonstrate the potential for significant reductions in acquisition and maintenance costs. One contractor has initiated gas-generator testing, and we anticipate that both contractors will complete the technical effort on schedule, in FY 1986. The potential applications for this class of engine include the joint vertical-lift [JVX] aircraft and the CH-47 or its replacement, and we plan to transition this technology demonstrator to full-scale engineering development of the modern technology engine [MTE] in the latter part of this decade.

Recent assessments of the potential for technology advances in aircraft propulsion have indicated that significant improvements are foreseeable by the year 2000—for example, increases in thrust-to-weight ratio approaching 100 percent and reductions in specific fuel consumption of the order of 30 percent appear to be suitable goals in this time period. We have formulated an integrated technology plan based on reasonable technological alternatives to achieving these goals, and we shall continue to initiate and pursue the requisite ambitious exploratory development efforts.

In the area of materials for propulsion systems, the Navy, Air Force and DARPA have embarked on a coordinated program to demonstrate the feasibility of using carbon/carbon composites in the hot sections of gas turbines for both unmanned and manned air vehicles. These materials offer the potential of operation at temperatures approaching 2500° K. Last year, I indicated our success with carbon/carbon exhaust nozzle liners in an F-100 engine. Currently, we have a variety of activities in progress, including applications to combustion chamber liners, turbine vanes, blades, and rotors, and complete exhaust nozzle configurations. In conjunction with more basic efforts on oxidation protection, fabrication architectures and methods, and the behavior of heterogeneous anisotropic materials, we anticipate that we will have a reasonable practical knowledge of carbon/carbon for these applications within the next three years.

I would like to conclude my review of our technology efforts with a discussion of our work in metal-matrix composites [MMC]. Our initial efforts in this area were oriented toward applications to aircraft and missiles. I reported last year on our MMC work in helicopter transmissions and aircraft wings. The thrust in MMC technology now is becoming increasingly oriented toward space applications. Therefore, building on the technology base which was developed to fabricate and qualify the twelve-foot long graphite fiber reinforced aluminum metal-matrix composite wave guide antenna boom for the NASA space telescope program and other projects in our MMC program, in FY 1985 we will initiate a long range program to develop MMCS for survivable space structures. This action was taken as a partial technological response to elements of the recently promulgated President's space policy, the

Defense Science Board study on the technology base, and the research and development objectives of the joint strategic planning document. Each of these documents, in one way or another, stresses the need for incorporating survivability measures into future military spacecraft. While it is recognized that structural survivability is but one element of the overall, it is acknowledged that the very long lead times (10–15 years) for systems integration of new materials and structures development mandates that this technology area be addressed at the earliest possible time.

Over the past few years it has become increasingly obvious that the requirements for space structures have become much more demanding. Pointing and tracking accuracy requirements have become more precise, laser, nuclear, and pellet hardening levels have increased, greater resolution is required by certain systems and higher power levels and temperatures are being demanded for postulated laser systems.

Our development of MMCS over the past few years is sufficiently encouraging to lead us to believe that these increased design requirements can be met at either the same or reduced weight of current spacecraft systems. Data has shown that a zero coefficient of thermal expansion can be achieved, thus the influence of high and irregular thermal exposures can be minimized. MMC do not outgas (evolve volatile recondensible materials) thus eliminating clouding of high precision optics. Furthermore, the structural strength of MMC is superior to baseline materials and graphite fiber reinforced epoxy at elevated temperatures. Finally, limited but significant laser and nuclear test results indicate that hardening is achievable.

In cooperation with NASA, the military departments, Defense Advanced Research Projects Agency [DARPA], and the Defense Nuclear Agency [DNA] are developing a broad ranging program plan to implement a comprehensive program in MMC for survivable space structures. The intent is to bring MMC to a stage of technology readiness for incorporation in military spacecraft by expanding and strengthening our technology base in areas such as high stiffness graphite fiber reinforced aluminum and magnesium composites, characterization of damping capabilities, stabilization of matrix distortion under thermal cycling conditions, and optimization of joining techniques. The program is intended to demonstrate by analyses, component fabrication and confirmation testing the utility of MMCS as spacecraft structural materials, while design option studies will address structural efficiency, performance, and survivability in hostile environments.

Any discussion on space and aeronautics would not be complete, without addressing the subject of research facilities. Not only must we be aware that proper facilities are absolutely essential to maintain our technological excellence in aeronautics, but we must not lose sight of the fact that the development of new facilities must lead the development of technology by several years. The efforts of the 94th Congress in the establishment of the national aeronautical research facilities program are now coming to fruition. The Vice President dedicated the national transonic facility last December, and we look forward to the meaningful research which will be conducted in that facility when it achieves operational status. We have been in close coordination with NASA regarding the repair and rehabilitation of the 40 $\times$ 80 $\times$ 120 wind tunnel at the Ames Research Center. The current plan to attain operational status by December 1985, will not adversely affect any defense programs. The availability of this facility is critical to the development of the JVX aircraft; however, the Navy has indicated that they can work around the delay with no adverse impact. We will continue to work closely with NASA to assist in whatever way we can to regain the test capability of the 40 $\times$ 80 foot tunnel.

I would like to conclude my remarks by noting that in response to an office of science and technology policy [OSTP] recommendation, a senior-level government, industry and academia committee was formed. This committee was asked to review—from a national perspective—government long-range aeronautical research and technology plans for consistency with the policy and to make recommendations to the President's science advisor where appropriate. The report of this committee was published last November. The findings and recommendations of the committee will certainly have far reaching impact on future aeronautical developments in the United States. We are working closely with NASA to respond to the President's science advisor with our coordinated plans to implement the committee's recommendation. I believe that through implementation of these plans we will greatly enhance our capability to develop superior military aircraft, and maintain a viable and productive civil aircraft industry which will be a long term benefit to the Nation as well as DOD. In this regard, I solicit your support of the NASA aeronautics technology programs.

Mr. Chairman, I would now like to touch on the subject of NASA/DOD coordination. As you are aware, there is a senior management group that oversees NASA/DOD aeronautic and astronautic activities. I, along with the Deputy Administrator

of NASA—Dr. Mark—co-chair this board known as the Aeronautics and Astronautics Coordinating Board. This board has as its responsibilities the planning of activities by the NASA and the DOD to avoid undesirable duplication and to achieve efficient utilization of available resources and the coordination of activities in areas of common interest to the NASA and the DOD.

In October of 1983, the board met to review the STS activities of both NASA and DOD. As a result of this meeting, a steering group was created to develop a NASA/DOD space transportation master plan. This plan would document NASA and DOD responsibilities, commitments, and resources for evaluation of operational space launch capabilities. The terms of reference include three principal topics: A baseline operations plan, a section on management issues and options regarding management of the shuttle and a section on new capabilities. This steering group, co-chaired by Bob Cooper and Hans Mark, is expected to complete the baseline operations portion of this activity to include the ELV initiative noted previously no later than June of this year.

This concludes my formal statement. Mr Chairman, I will be pleased to accept any questions the committee may have.

Questions of Senator Gorton and the Answers Thereto

ELV FUNDING

Question. Could you comment on the mechanism by which the development of the ELV's will be funded?

Answer. The current mechanism requires that the contractor will fund the upfront Research and Development (R&D) costs for the vehicle and the launch facility costs. The contractor will amortize the upfront R&D costs across the first ten vehicles. DoD will commit to procure at least two ELV's/year for five years beginning in FY88.

Funds will be required one year prior to launch, with the government guaranteeing termination liability if the program is cancelled. This mechanism results in no government funding until FY88, but government commitment starts in FY85.

WHY INDUSTRY FUNDING FOR ELV

Question. Since, as I understand it, DoD will ultimately pay for the development costs of the ELV's, why are you proposing to have industry initially put up the money to fund the development?

Answer. The statement that DoD will ultimately pay for the development costs of the ELV's is accurate. Our proposal to have industry fund the development is prompted by two advantages to the government. The first deals with the President's policy on the Commercialization of Expendable Launch Vehicles to encourage U.S. private sector development of commercial launch operations, and the second deals with the size of the DoD investment in the FY85–87 budget.

The DoD investment in the ELV program will be $8 million in FY85. This $8 million is required to begin the integration design of the selected satellites that will fly on the commercial ELV's. If DoD proceeded as usual (i.e., funding R&D upfront), the initial appropriation for FY85 would be on the order of $500 million. As proposed, the outlay of DoD funds will not occur until the first vehicle buy in FY88. DoD plans to use already programmed Shuttle flight charges in FY88–92 to partially offset the ELV purchase price.

ON-ORBIT ALTERNATIVE APPROACH

Question. It has been suggested that, as an alternative to your present approach to assured access to space, it might be worth considering the purchase of additional spacecraft or satellites for storage *on-orbit* rather than on the ground, thereby enabling you to contend with a temporary non-availability of the Shuttle if one occurred. Could you comment on this alternate approach and compare its cost with the cost of the present approach of purchasing ELV's and the additional spacecraft?

Answer. The DoD has reviewed both on-orbit sparing and quick response to orbit concepts and determined on-orbit sparing to be most cost effective for existing space capabilities. In the far term, ground reconstitution along with other potential solutions will receive continued evaluation. However, the near term strategy of on-orbit sparing will allow us to fully exploit the capability of the Shuttle, while avoiding the costs of developing a new family of satellites compatible with a survivable launch system.

The costs for on-orbit reconstitution would be a function of whether a dedicated Shuttle mission would be required. The actual costs would roughly equal the current Shuttle costs for the specific payload.

The cost comparison for an ELV system would depend on whether the price to fly that ELV equaled a Shuttle flight and the amount of integration costs required to augent the Shuttle configured spacecraft to the ELV. These costs would also vary with each specific payload.

IUS FAILURE IMPACT

Question. Due to the IUS failure, NASA has postponed the deployment of its second and third TDRS satellites until 1985. a. How does this postponement affect DoD's launch plans and mission objectives? b. How long can DoD afford a TDRS system that is only partially operant?

Answer. a. The IUS anomaly last spring has delayed DoD plans for launch of DoD satellite missions. The current recovery plan for the IUS could support a return to launch operations in late 1984.

b. The DoD does not rely directly upon the TDRS satellite constellation for support; therefore, a delay in acquiring full TRDSS coverage would not cause a problem. The DoD has other options to satisfy our requirements if the TDRSS deployment becomes very lengthy. NASA will use the TDRSS capability to provide real-time, continuous, worldwide communication coverage of STS on-orbit operations.

SOVIET SPACE ACTIVITIES

Question. It has been reported in Aviation Week that the Soviet Union is developing a large laser-equipped prototype military spacecraft for launch on its heavy Saturn 5-class booster. This report also says that the spacecraft is being developed to attack U.S. satellites and is expected to be launched within the next two years. To what extent is this report accurate. . . .?

Answer. Major new capabilities in the next 10 years will result from the successful introduction of a reusable space transportation system, a space tug, a military space plane, and a heavy-lift launch vehicle. Any delay in development of the heavy-lift launch vehicle will seriously affect several other Soviet space systems.

[Deleted.]

Question. It has been reported in Aviation Week that the Soviet Union is developing a large laser-equipped prototype military spacecraft for launch on its heavy Saturn 5-class booster. This report also says that the spacecraft is being developed to attack U.S. satellites and is expected to be launched within the next two years. What other trends or evidence are there that would lead you to believe that the Soviets will soon have an air-based or space-based anti-satellite technology.

Answer. Currently the most serious threat to U.S. space systems is [deleted.]

The Soviets also have a strong technology program related to the exploitation of charged and neutral particle beams as potential weapons (PBWs) [deleted.]

The Soviets have a well-funded research program to develop new types of ultra-high power microwave devices. [Deleted.]

Question. According to your testimony, potential military applications can be derived from Soviet scientific/developmental satellites carrying imaging radar systems. Just what are the potential military implications you have derived from these "scientific" endeavors?

Answer. Soviet Venus-15 and Venus-16 spacecraft have recently mapped the Venutian surface [deleted].

[Deleted.]

STRATEGIC DEFENSE INITIATIVE

Question. Concerning the Strategic Defense Initiative, your testimony indicates that in [deleted] you will initiate on-orbit feasibility experiments of the Talon Gold tracking and pointing technologies. Will the Talon Gold experiments require the use of the Shuttle, and will any other experiments or demonstrations relative to the Triad program and the Strategic Defense Initiative require the use of the Shuttle?

Answer. The Talon Gold experiment will use the Shuttle to carry this pointing and tracking experiment into space. No other Triad experiment is space-borne; both the Alpha laser experiment and the Large Optics Demonstration Experiment (LODE) will be conducted entirely on the ground.

The Joint Air Force/Defense Nuclear Agency program, Cryogenic Infrared Radiance Instrumentation for Shuttle (CIRRIS) will make synoptic measurements of infrared earth limb signatures. The first flight will be in [deleted.]

While certain other SDI efforts will certainly involve experiments conducted in space, none presently has specific plans for the use of the Shuttle.

Question. Do the Soviets have or are they developing technologies similar to those that comprise our Triad program?

Answer. We believe that the Soviets have a program to develop the technology for space-based directed energy weapons.

[Deleted.]

FUTURE ASAT TESTS

Question. Taking into consideration the Tsongas amendment to the fiscal year 1984 DOD Appropriations bill, which concerns testing ASAT technologies against objects in space, what ASAT tests are you planning following the [deleted] test?

Answer. Subject to satisfying the conditions of the Tsongas amendment, a series of ten live fire launches is planned beginning in [deleted.]

DETERMINATION OF ASAT NEED

Question. Has a determination been made that ASAT tests against objects in space are necessary for the national security, and if not, when will this determination be made?

Answer. The formal determination of need required by the Tsongas amendment for ASAT tests against objects in space has not yet been made by the President; however, the ASAT report recently forwarded to the Congress on 31 March 1984, clearly details the national security requirements and problems and possibilities of arms control for the ASAT program.

ASAT TREATY PROGRESS

Question. What progress has been made in negotiating a treaty with the Soviet Union for a mutual and verifiable ban on ASAT's?

Answer. Very little progress has been made in negotiating a treaty with the Soviets; however, considerable progress has been made in developing arms control options, that will make any eventual treaty a more effective, verifiable and endurable agreement.

The major problems for ASAT arms control discussed in detail in the Report to Congress on U.S. Policy on ASAT Arms Control have hindered our efforts to develop effective arms control measures. In fact, it appears that the problems of verification tend to be greater the more comprehensive the limitation. Some less sweeping options under study would seek to limit or ban specific types of weapons systems. Since we must, in any event, be able to protect our satellites against threats that could be developed without our knowledge, there is a premium on finding ways to limit through arms control those ASAT systems that create the most difficult survivability problems. We are searching for limits on such systems which are effectively verifiable and which allow us to protect U.S. and allied forces from threatening Soviet satellities, such as targeting statellities. Other options under examination would regulate certain threatening activities related to space.

The future of space arms control must also be considered in the broader context of U.S.-Soviet arms control relations. Soviet actions in other negotiating fora and Soviet actions with respect to compliance with existing arms control agreements must also be taken into account to determine the most appropriate course of action for the United States concerning arms control for outer space. In the meantime, the U.S. evluation of possible future courses for ASAT arms control will be judged not simply in light of their ability to limit damage to space objects, but also in light of their contributions to the basic objectives of deterring terrestrial conventional and nuclear conflict.

ASAT POLICY FOR USE

Question. Under what circumstances would the U.S. use its ASAT capabilities, and what is the U.S. policy regarding a response to a Soviet ASAT attack against a U.S. satellite.

Answer. The two questions are closely related in that they would require NCA decision. Any U.S. response to a Soviet attack must be considered in the context of the world situation at that moment. The United States need for an ASAT is defensive in nature—to have the capability to decrease the threat to U.S. and allied naval and land conventional forces and deter attacks against out satellites.

Question. Your testimony states that the Soviet Union could launch a space plane by the 1984-1985 time frame, and that it could be used to ferry cosmonauts to

manned space stations and to conduct reconnaissance missions. What are we doing to develop our own space plane, when could it be available, and how would its capabilities compare with those of the Soviet space plane?

Answer. At the present time, we do not have an active program to build a space plane. Both the Air Force and NASA have studied the technology base, capabilities, and system requirements and believe that such a plane could be built. The Air Force has two efforts examining different aspects of the space plane question.

One effort is examining the requirements for space planes and doing concept designs to meet generic groups of requirements (e.g., astronaut ferry and rescue, reconnaissance, satellite inspection, space station resupply, payload launch, etc.). These studies are defining the technology items that are high risk—the ones that must be resolved if a space plane is to be built.

The other effort is the Advanced Military Spaceflight Technology Program which is intended to take identified high risk technology, including manufacturing technology, and develop it. The goal of the program is to develop initial technologies to the point that a production decision could be made in 1990 with no technology risk considered higher than moderate. This program has been zeroed in the Congress without prejudice for two years.

We have estimates on space plane production from a number of major space system and aircraft corporations. Depending on the program type and funding level, these estimates range from 5 to 10 years.

The capabilities of these conceptual programs depend on the selected mission. In general, we have assumed a requirement of 10,000 pounds to polar orbit with runway launch and recovery as a requirement start point for technology development.

IMPACT OF PAM-D FAILURE

Question. How will the recent failure of the PAM-D upper stage on the February Shuttle mission affect DOD's space launch schedule and mission objectives?

Answer. Currently no STS DOD missions require the PAM-D upper stage. The Global Positioning Satellite (GPS) will use a related but more powerful booster, the PAM-D II. The first GPS mission is scheduled to fly on the STS in October 1986. There is a slight chance that results of the anomaly investigation on the PAM-D failure may impact the PAM-D II. The PAM-D II uses a different motor (IPSM vs Star 48) and a different nozzle (carbon-phenoic vs carbon-carbon). These are areas that are suspect on the PAM-Ds that failed. The PAM-D II motors will be test fired for the first time in April 1984. The first commercial PAM-D II mission is scheduled for summer 1985.

An expendable launched GPS mission is currently being delayed until resolution of the PAM-D flight anomalies. The upper stage on the Atlas expendable booster uses a Star 48 motor.

FIFTH ORBITER

Question. NASA has now been presented with another proposal to commercially develop a fifth orbiter. What concerns would you have about a privately-owned fifth orbiter, and what national security requirements would a commercial owner of a fifth orbiter have to meet relative to his Shuttle operations?

Answer. We welcome and support U.S. business interest in the Shuttle program. The ultimate acceptability to DoD would depend on the terms and conditions associated with the commercial owner. Prospective private interest procurement of a fifth orbiter would have the potential of reducing Space Transportation System costs which are now almost solely funded by the government. We have nothing against the concept, in principle.

NASA/DOD MASTER PLAN RESULTS

Question. In your testimony, you have stated that the NASA/DoD Space Transportation Master Plan steering group has already begun meeting. What are the results to date of the steering group's meetings?

Answer. To date, the steering group has agreed on the terms of reference for the study. It was agreed that the basic plan would address three major areas: baseline operations, management issues/options, and new capabilities.

The steering group, co-chaired by Dr. Robert Cooper and Dr. Hans Mark, has tasked both NASA and DoD working groups to prepare the baseline operations portion of the plan and provide a report to the steering group in May.

The management issues and new capabilities sections of the plan will require that both NASA and DoD have a clear understanding of their respective needs and requirements. Therefore, the steering group decided that these sections would be deferred until some later date, while each activity completes their own internal study.

Senator TRIBLE. Thank you, gentlemen.

[Whereupon, at 10:28 a.m., the subcommittee adjourned, to reconvene at 10:30 a.m., the same day.]

[The subcommittee reconvened at 10:32 a.m.]

OPEN SESSION

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. This is the last of 4 days of hearings by the Subcommittee on Science, Technology, and Space on the fiscal year 1985 NASA authorization.

On the first day, NASA Administrator Jim Beggs and his Deputy, Hans Mark, presented the proposed fiscal year 1985 programs and budget, and NASA's Aerospace Safety Advisory Panel testified on the space transportation system.

Our second day of hearings focused on the administration's proposal to develop a permanently manned space station. Following this hearing, the subcommittee examined NASA's space science and applications programs as well as its advanced communications technology satellite program.

Today we are here to consider NASA's aeronautical research and technology programs as well as our world position in aeronautical technology and sales. Over the past 68 years, NASA and its predecessor, the National Advisory Committee on aeronautics, have cooperated with private industry in a unique and constructive partnership that has matured to provide this Nation with the world's most advanced aeronautical technology.

Because developing new aeronautical technology is a rigorous and expensive process, and because the risks of assembling theoretical and experimental information into significant bodies of knowledge are great, Federal governmental assistance is appropriate.

Nevertheless, the issue has been and still is, "To what extent should the Government assist in aeronautical research and technology?" In deciding upon the degree of Government involvement, we need to determine where the risks for the private sector are too great and where the potential payoffs are too distant.

In exploring and developing new aeronautical technology, we should also be mindful of the growing inroads that our foreign competition is making in the world aviation market. Our once-unchallenged position of preeminence in this market is now being challenged, and as a result our own commercial aircraft industry has shrunk. Incorporating the latest technology in a timely manner is becoming increasingly important to meeting the challenge of our foreign competition.

NASA's aeronautical test facilities and professional expertise are invaluable national assets which should not be underutilized nor misdirected. By taking full advantage of these technological and professional resources we should be able to assure U.S. leadership in aeronautics and to reap the economic benefits such leadership provides.

In addressing these issues today, we welcome a panel of Dr. Karl Harr and Mr. Jim Krebs of the Aerospace Industries Association of America and Mr. Harvey Album of the American Institute of Aeronautics and Astronautics, who will be introduced briefly by Mr. Johan Benson.

STATEMENTS OF JOHAN BENSON AND HARVEY ALBUM, CHAIRMAN, AIRCRAFT DESIGN TECHNICAL COMMITTEE, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS; JAMES N. KREBS, AEROSPACE INDUSTRIES OF AMERICA, INC.; AND KARL G. HARR, JR., PRESIDENT, AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

Mr. BENSON. Thank you very much, Mr. Chairman. I am here substituting for Dr. Alan Lovelace, who was unable to attend the meeting.

The American Institute of Aeronautics and Astronautics is a nonprofit technical professional society with over 34,000 members who are engineers, scientists, and students engaged in every sector of the aerospace profession from industry to Government to the universities.

To promote scientific and technical achievements we have 51 committees covering all aspects of the aerospace profession. The views presented in this testimony were formulated by the AIAA Ad Hoc Advisory Committee on National Aeronautics. Members who are selected for this committee have expertise and knowledge that span research, technology advancement, development and operational requirements, as well as all major aeronautical discplines.

The group was also chosen to provide a careful balance of backgrounds from all segments of the field, including commercial and military transport, general aviation, helicopters, and all forms of military aircraft. The group came from industry, the universities, the military services, nonprofit research institutes, and represents six of our technical committees.

The special perspective, therefore, presented in this testimony is that of knowledgeable professionals from every sector of the field. The testimony today will be presented by Mr. H. Harvey Album, program manager for aeronautics of SRI International, who is chairman of the Ad Hoc Advisory Committee on National Aeronautics and also chairman of our Aircraft Design Technical Committee.

Mr. Album.

Mr. ALBUM. Mr. Chairman, we have a statement that we would like to submit which is fairly lengthy.

Senator GORTON. Your entire statement will be included in the record.

Mr. ALBUM. I will not try to read it.

Senator GORTON. We appreciate your summary.

Mr. ALBUM. I will just summarize a few of the major points that are in our statement.

I think you really hit the nail on the head in your introductory statement in regard to the changing situation that we are witnessing in aeronautics.

Senator GORTON. Excuse me. This Senator has been very inattentive to his bells and we are at the end of a rollcall right now. So I am going to have to recess this meeting for about 10 minutes. I am sorry to interrupt you, but we will let you begin again.

Mr. ALBUM. Fine, sir.

[A brief recess was taken.]

Senator GORTON. Please accept my apologies and, Mr. Album, continue.

Mr. ALBUM. Yes, sir.

I think the important point here is that we have been witnessing well documented changes in the relative rate of progress in aeronautics. In the commercial sector oif aeronautics, friendly foreign countries are able to field highly desirable products in competition with our own products. We have been witnessing increases in the rates of foreign aircraft sales relative to our sales. In the military area, there has been rapid advancements on the part of the Soviet Union in developing and producing fairly exotic aircraft. We must maintain our surperiority in developing civil and military aircraft in order to maintain both the economic advantages of aeronautics and, certainly, the defense advantages to our Nation.

Now when we have seen these major changes taking place over the last 5 years and we know what we are doing. It should be obvious that little, small changes in programs and small changes in the way we are doing business, in one direction or the other, are not going to change these trends. We have to address this problem, I believe, in a serious manner.

There has to be an increase, a marked increase, in the pace of our advancements in aeronautics. There has to be a change in the way in which we conduct business so that we are able to do the kinds of things we do in R&D much better and more effectively. That is what we should basically be addressing.

I recognize in these times of difficult budgets that one can have the feeling that progress is being made by shifting moneys from one part of the NASA aeronautics program to another part of the program. Basically what we are doing here is we are robbing Peter to pay Paul. In the process of trying to help certain high priority programs, many of which we have recommended as being high priority, we find that other high priority programs are being stunted, terminated, and we are losing gains in one area to make gains in another area. So I think we must address this problem in its entirety and expect that the only way we are going to make changes in the trends in aeronautics is to make major meaningful changes in our R&D activities.

Now I would like to address a few things in this regard. In prior testimony in the House, we made eight recommendations. for major changes that are necessary in order to advance military and civil aeronautics. Some of these recommendations apply to NASA and some of them apply to the DOD. I will not go into all of them now, but I would like to address a few that apply to NASA and our Nation's overall aeronautical R&D activities.

First of all, we recommend a marked increase in emphasis and focus on aeronautics in NASA. Aeronautics represents a relatively small percentage of the NASA budget. Yet, it represents a very important contributor to the American economy and to the defense of

our Nation. Therefore, aeronautics should carry equal emphasis with space activities in the management structure of NASA. We recommended a separate organizational structure for aeronautics in NASA in the manner of the earlier NACA.

We recommended the establishment of a national aeronautics advisory committee with representatives, top level representatives, of all major segments of aeronautics in the United States. I am happy to say, Mr. Chairman, as you know, that that committee has been established under the White House since the time of our recommendation. This is the analogous committee to the old NACA, National Advisory Committee for Aeronautics.

What we do not have is the technical subcommittee structure that existed over those 40 years of the NASA and which served very well to integrate, at the grassroots level, the various aeronautical disciplines from all sectors of aeronautics. That has yet to be established.

NASA does have advisory committees, but these serve completely different types of functions than would be performed by such national committees, which basically were formed for joint consultations on problems, discussions of plans and programs for the future. There is a difference between reviewing programs that one agency planning to do and trying to put together programs that you think ought to be done on a national basis for the future.

We recommend an increase in pace for aeronautical research and technology. I believe you pointed out that there has not really been much change in the NASA budget over the last couple of years on a constant dollar value basis. The total NASA aeronautics budget today is slightly above the lowest level it has been over the last 10 years in real terms.

We are delighted that there is a real increase proposed this year. I think we are starting to see the effects of the national aeronautics policy for the first time. The current total NASA aeronautics budget—which takes into account NASA facilities, people, and the R&D contract budget as well as construction of facilities—is currently submitted at $697.1 million. That is a 17-percent increase from fiscal year 1984.

Even though this budget is coming off a very low level, we are very happy to see the increase because that is something solid when one starts to talk about making changes. We believe that these increases should be continued over the next 4 or 5 years, steady increases. We do not believe that you should necessarily just plunk large amounts of money haphazardly into the NASA aeronautics program, but there should be measured increases to reach a level of at least the average of 1979 and 1980 on a constant dollar basis.

We strongly support the NASA program and its budget for this year. However, we are very concerned about the balance between the different types of work going on in NASA, that is the applied research work, generic technology, and systems technology programs.

We have four major recommendations for a more aggressive and well-balanced NASA program. The first one is to increase funding and particularly manpower for broad-based applied research. Applied research is the cutting edge of advances in aeronautics. This

is where all the fundamental new concepts come from, the innovations, the methodologies, the knowledge and the know-how. There are many advances that NASA would cite in terms of what they have done over the last 20 years, and I think you would be able to trace every one back to their applied research programs. We believe that there is a huge shortfall in the amount of applied research coming from NASA. The amount of applied research should be possibly doubled or tripled.

The wonderful thing about applied research area is that you can have lots of small efforts going on and they are not terribly expensive individually. Technology programs—and we have recommended a number of them—are extremely expensive. They involve a lot of hardware, flight tests, and a great many people all narrowly focused on a small number of efforts over a period of many years.

Picture a situation of Einstein sitting there with his pad and pencil thinking up a new theory. I imagine if you figured out how much it cost for his salary over a period of time it would not look that big. Yet, the impact of good research can be enormous. If you have very talented people doing innovative thinking and experiments, they can provide the advances that will completely upstage the competition over the long term.

We believe that NASA's applied research is not as aggressive, systematic, or plentiful as it once was. In our statement we cite a number of other knowledgeable groups who have made exactly the same observations and recommendations, extending back over a period of about 10 years, and we are witnessing the effect of this shortfall at this time.

We feel at the same time that there are places where NASA should spearhead technology and technology demonstration programs. These must be carefully and judiciously selected because of the deleterious effect that they could have on the applied research programs in terms of sopping up both manpower and moneys. But we have recommended a number of these programs and these programs should be pursued, the really important ones which fit properly relative to what industry and the military should naturally be doing.

We recommend that NASA accelerate its research and technology work which is applicable to high performance military aircraft and to helicopters that would apply to the next generation of military aircraft. Within the last year three new major military aircraft development programs have been announced and they will begin this year. There has been a lot of NASA work that has been underway over the last 10 years which is applicable to these programs. It is very important that NASA complete and feed its R&T results into these military programs, now that we know when the systems are coming and what the technology cutoff dates are for these systems. The planned technology cutoff dates are between 1987 and 1990. Therefore, NASA should make sure that those NASA programs that can impact these new military programs should be paced to properly match these cutoff dates. We cite a few of these NASA programs in our testimony.

Our submitted written statement covers two additional recommendations, including our advice to proceed with the planned 9-ft

prop fan flight-test program and improvements in university research programs.

In conclusion, I would like to say that we think it is very good that there is an increase in the 1985 NASA aeronautics budget. We are happy to see that the aeronautics policy review committee has been established. These are really the only indications that we see of any changes from the national aeronautics policy or any attempts to redress the negative effects we have been seeing in our relative rate of aeronautical progress. But, gentlemen, this is not enough or not anywhere near enough. There is still a long way to go and if we continue doing business as usual we can expect the trends to continue, also as usual.

Thank you, sir.

[The statement follows:]

STATEMENT OF DR. ALAN M. LOVELACE, VICE PRESIDENT, PUBLIC POLICY AND H. HARVEY ALBUM, CHAIRMAN, AIAA ADVISORY COMMITTEE ON NATIONAL AERONAUTICS, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

INTRODUCTION

The American Institute of Aeronautics and Astronautics (AIAA) is a nonprofit technical professional society with over 34,000 members who are engineers, scientists, and students engaged in every sector of the aerospace profession, from industry to government to the universities. The Institute's professional membership is divided into 68 sections around the country. To promote scientific and technical advancements, we have 51 technical committees covering every aspect of the aerospace profession.

The views presented in the testimony today were formulated by the AIAA Ad Hoc Advisory Committee on National Aeronautics.* The members selected for this committee have expertise and knowledge that span research, technology advancement, development, and operational requirements, as well as all major aeronautical disciplines. This group was also chosen to provide a careful balance of backgrounds from all segments of aeronautics, including commercial transports, military transports, general aviation, helicopters, military fighters and bombers, trainers, and attack aircraft. The group came from industry, universities, the military services, and nonprofit research institutes. Experts from NASA were not included in order to avoid the appearance of a conflict of interest. The members of the Ad Hoc Advisory Committee on National Aeronautics included the chairmen, or their representatives, from AIAA technical committees on Aircraft Design, General Aviation, Air Transportation systems, Structures, Propulsion, and Guidance and Control. The special perspective on the issues presented in this testimony is that of knowledgeable professionals from every sector of aeronautics who were able to reach a high level of accord because of their common interest in advancing this nation's aeronautics capabilities.

The testimony today will be presented by H. Harvey Album, Program Manager for Aeronautics, SRI International, who is Chairman of the Ad Hoc Advisory Committee on National Aeronautics and also Chairman of Our Aircraft Design Technical Committee.

NATIONAL AERONAUTICS POLICY

The White House introduced a National Aeronautics Policy in November of 1982.[1] That policy resulted from a wide ranging debate and White House study that ex-

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* The primary points made in this testimony represent a consensus of judgments of the members of this Ad Hoc committee. A consensus means that a greater-than-two-thirds majority of this committee shared the opinions presented. Opinions were formulated by a structured assessment process that included closed voting on all points in the testimony. Hence, any given point of view does not necessarily represent the individual opinion of every member of this committee, their respective organizations, or the Institute as a whole.

[1] "Aeronautical Research and Technology Policy," Volume 1, Summary Report, Executive Office of the President, Office of Science and Technology Policy (November 1982).

tended from Congress to every related agency in the Executive Branch of Government. The Government gathered facts and called upon the views of many organizaions involved in aeronautics in the private sector. We were honored to provide the White House the outside independent panel that reviewed the proposed policy in the final stages of development.[2] All of the thirteen improvements we suggested were incorporated in the final policy. This total process resulted in a clear understanding in government of the unique role and importance of aeroanutics to the economy, security, and welfare of the United States. The policy sets forth national goals for aeronautics and supporting goals for aeroanutical research and technology.

The policy debate is now over and it is the application of the policy that is in question. Policy can represent nothing more than a piece of paper if it is not implemented. The entire purpose of the policy will be defeated if it is not applied correctly or if the detailed programs are poorly chosen. Our progress in aeronautics and relative world position in this critical area will continue to slip, if we go on conducting business at the same inadequate pace and in the same manner as we have been doing for more than a decade.

Foreign aeronautics continues to advance relative to that in the United States. In the military area, for instance, the Soviet Union is developing the supersonic "Blackjack" bomber, which is larger than the B-1B. The B-1B is a powerful and effective subsonic strategic bomber that uses standoff cruise missiles and can penetrate the Soviet Union subsonically at low altitudes. This bomber will become operational in 1986. The Blackjack bomber, first flown in 1980, is a follow-on to the Tupolev supersonic Backfire bomber and the Soviet supersonic transport. The modern Backfire and Blackjack bombers represent not only a strategic peril, but they are a major threat to our Naval fleets over large portions of the world's oceans. We have no equivalent operational long range bombers that are designed and assigned to attack the Soviet Navy.

The Soviets continue to develop, test, and deploy new fighters and fighter bombers. The Soviet Foxbat (MIG-25) interceptors and reconnaissance aircraft, developed two decades ago, are still faster and fly at higher altitudes than any of our fighters. Last year the Soviet Union deployed the Foxhound (MIG-31), a more advanced follow-on to the Foxbat. In addition, last year they deployed two other new fighters, the Fulcrum (MIG-29) and the Flanker (SU-27). Although our fighters are excellent aircraft and are superior to the Soviet fighters in many respects, we must have far superior aircraft to outweigh the sheer numbers of opposing forces. The F-14, F-15, and F-16 all entered operational service during the 1970s. The F-18 is the only aircraft to have entered service in the 1980s. We have been studying the Advanced Tactical Fighter since 1970. There must be marked improvements in our military aircraft for the 1990s. The race is too close for comfort.

On the commercial scene, foreign aeronautical firms continue to progress with gains in many areas. Table 1 shows the increase in the percentage of the total value of foreign civil and military aircraft imported into the United States relative to the value of United States aircraft exported to other countries over a recent five-year period.

TABLE 1.—VALUE OF AIRCRAFT IMPORTS RELATIVE TO EXPORTS FOR THE UNITED STATES

[In percent]

Year	Civil aircraft	Military and civil aircraft
1978	8	5
1979	8	1
1980	12	1
1981	16	13
1982	23	16

Source: "Aerospace Facts and Figures 1983/84," Aerospace Industries Association of America, Washington, D.C. (July 1983).

These figures reflect the growing quality and attractiveness of foreign civil aircraft designs, as well as other sales inducements being offered. Fortunately, most of the foreign aircraft sold here have over 70 percent of their components manufactured in the United States.

[2] Review of the White House Aeronautics Policy by the Ad Hoc AIAA Advisory Committee on National Aeronautics, Seattle, Washington (26 August 1982).

In a major move last year, McDonnell Douglas stopped development on two new civil aircraft and not long ago, Lockheed withdrew entirely from the commercial transport business. It is true that all commercial aircraft companies, foreign and domestic, have been under great pressure due to a weak world economy coupled with relatively high interest rates. Nevertheless, the number of foreign companies in civil transports is not diminishing; in fact, many are expanding their product lines with the support of forward-looking governments. Although our aircraft companies are far from stagnant in developing news products and are incorporating a steady flow of new technology into future designs, we are witnessing a change in the relative rate of progress and a rapid emergence of strong foreign commercial competition in almost every area of aeronautics.

Competition from friendly foreign countries and the challenge to the world leadership position that the United States has held in aeronautics since the end of World War II is not basically unfair, immoral, or sinister. There is nothing fundamentally wrong with friendly foreign governments supporting their aircraft industries in the same manner as these governments own, or provide financial support for, other industries in their countries. The trend toward licensed manufacturing and cooperative aircraft development programs between companies in our country and companies in friendly foreign nations will undoubtedly increase, where appropriate, yielding better products and benefits to both sides.

Foreign aircraft manufacturers will continue to rely heavily on United States components, and United States suppliers will provide a wide assortment of products and services for the growing aviation industries of many countries. The capability to manufacture aircraft in foreign countries may result in more aircraft purchases for defense and improved internal civil aviation systems for many countries than would otherwise be possible. Commercial competition with friendly countries should stimulate us to accelerate our technical progress, increase our efficiency, and better meet our customer's needs. Better and more economical aircraft as a result of competition should expand the growth of worldwide aviation with economic benefits to all nations.

Still, for national security and economic reasons, the United States must strive to retain its world leadership position in aeronautics. An AIAA National Aeronautics Advisory Committee recommended to the White House and to Congress in 1982 that at least eight major changes be made to achieve this nation's aeronautics goals.[3] [4]

(1) Emphasize, upgrade, and integrate the NASA's aeronautrical R&T functions and activities by establishing a separate aeronautical management structure within NASA in the manner of its forerunner, the National Advisory committee for Aeronautics (NACA).

(2) Substantially increase NASA's output of aeronautical research and technology.

(3) Provide financial incentives to stimulate private-sector investments in aeronautical R&D.

(4) Provide adequate competitive financing through the Export-Import Bank to facilitate foreign sales of United States civil aviation products.

(5) Emphasize regular military development of austere, advanced, flying prototype systems.

(6) Streamline the military aircraft and weapon procurement practices.

(7) Institute a better process for determining the operational and design requirements of military aircraft.

(8) Increase government support and stimulate industrial assistance for educating high-quality engineers and scientists to meet the future needs of American aeronautical R&D.

Since these points were covered in detail in prior Congressional testimony in 1982,[4] I will not expand on them here except to observe what has happened since that time. When we made these recommendations, we also predicted that the establishment of the National Aeronautics Policy would represent a turning point in the progress of American aeronautics.[4] Although slow in coming, there are now some indications that this prediction may eventually prove correct.

The AIAA National Aeronautics Advisory Committee that was convened at that time pointed out the need to reinstitute the "NACA" advisory board and its techni-

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[3] "Implementation Steps for National Aeronautics Policy." Meeting of Ad Hoc AIAA Advisory Committee on National Aeronautics Policy, Washington, D.C. (30 September 1982); recommendations provided to Dr. J. Montulli, Office of Science and Technology Policy, Executive Office of the President, (2 October 1982).

[4] Statement of H. Harvey Album, "Aeronautical Research," Hearing before the Subcommittee on Transportation, Aviation and Materials, Ninety-Seventh Congress Second Session (14 Decemer 1982) (No. 156), U.S. Government Printing Office, Washington, D.C. (1983).

cal subcommittee structure, consisting of leaders from all sectors of aeronautics, including the Air Force, Navy, Army, NASA, FAA, industry, and universities, and covering all aeronautical disciplines. The White House National Aeronautics Policy study also stated that ". . . since the creation of NASA in 1958 and the elimination of the NACA Advisory Board, senior aeronautical policy coordination between NASA, DoD and industry has weakened." [4] Dr. George Keyworth, Science Advisor to the President, in announcing the new National Aeronautics Policy said, "We want to see another step taken to improve the general coordination of aeronautics activities.

The old NACA Advisory Board served a useful purpose in bringing the various government and industry interests together periodically. In the 25 years since NACA's elimination, that mechanisms has been increasingly missed, so we recommend the reinstitution of a high-level NASA-DoD-industry committee that would meet at least once a year to review all aeronautical R&T policies. . . ." [5] The White House followed through on this recommendation and established the Aeronautics Policy Review Committee in 1983. In its first report, this committee recommended a number of important steps to implement the National Aeronautics Policy, which included roughly 70 percent of the actions our AIAA advisory committee recommended. The establishment of this Aeronautics Policy Review Committee under White House direction is an extremely important first step toward bring about the changes needed for a major upturn in the progress of American aeronautics.

However, the most effective links connecting our nation's aeronautical R&T efforts under the NACA were the technical subcommittees. Such technical subcommittees, with a truly national orientation, still must be established. These subcommittees are necessary if we wish to bring about the same grassroots level of cooperation, natural flow of plans and programs, and interchange of results that existed among all aeronautical sectors for over 40 years under the subcommittee structure of the old National Advisory Committee for Aeronautics. National technical subcommittees would be important to efficiently plan and conduct aeronautical R&D activities in all government agencies and in the private sector—not just in NASA. It is true that all government agencies involved in aeronautics, including NASA, have outside advisory groups to review their plans and programs. What is missing are the common technical committees for regular joint consultations, among all appropriate participant groups in given technical areas, on future needs and opportunities, problems, progress, current programs, future plans, and cooperative efforts.

Regarding the other points in our recommendations, we note that the Export-Import Bank did improve its financing of foreign sales of United States civil aviation products last year. We must retain our nation's leadership position in aeronautics by strong, positive steps in research and development, foreign trade, financial and tax incentives, laws governing internal commerce and by maintaining the growth of air transportation in the United States. Where foreign governments step in to bias commerce, so too should our government play a role to balance the competition.

The pace in R&T has not picked up. There was no significant increase in the total NASA budget for aeronautics from fiscal year 1983 to fiscal year 1984 beyond that required to keep pace with inflation. These NASA's aeronautics budgets were just about the lowest in over a decade, in real terms. In addition, there has been no other apparent increase in the emphasis on aeronautics in NASA.

NASA AERONAUTICS BUDGET

Total aeronautics budget

We strongly support the proposed NASA aeronautics budget for fiscal year 1985. The total proposed budget for aeronautics is $697.1 million, which represents a 17 percent increase over fiscal year 1984. Such an increase is not only consistent with the National Aeronautics Policy, it is the first real indication of positive steps that can be expected from that policy. Similar percentage increases should be planned over the next several years until the NASA aeronautics budget is at least brought back to the average level for fiscal year 1979 and fiscal year 1980 including corrections for inflation. These rough planning estimates should be adjusted upward or downward in any given year, depending upon the merits of the programs submitted by NASA and the demonstrated progress of this agency.

General thrusts

The "tug of war" between OMB and the Congress over the NASA aeronautics budget over the last several years has apparently been mostly over the balance be-

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[4] Dr. George A. Keyworth, Science Advisor to the President, and Director, Office of Science and Technology Policy, Executive Office of the President, "A New Federal Policy for Aeronautics Research and Technology," remarks to Aero Club of Washington (9 November 1982).

tween R&T Base Programs and Systems Technology Programs. OMB appears to have been mostly in the favor of the R&T Base Programs and opposed to Systems Technology Programs. Congress, on the other hand, has defended the Systems Technology Programs. There are good arguments for both kinds of programs and dangers in the extremes.

The NASA aeronautics budget is about 10 percent of the total government expenditures for aeronautical R&D. In addition, we estimate that industry invests private funds in aeronautical R&D that are more than five times greater than the total NASA aeronautics budget. There are three main reasons whey the NASA aeronautics budget is important, in spite of the much larger R&D investments from other sources:

(1) NASA funding and manpower has traditionally gone into the high-leverage front end of the aeronautical R&D process, where the costs are lowest, payoffs the broadest, and utility the riskiest. Yet, the great innovations in aeronautical capabilities have their roots in this part of the process.

(2) NASA funding maintains central national laboratories that have been centers of excellence for conducting long-term aeronautical research that has led to major innovations for both military and civil aeronautics.

(3) This funding has traditionally provided and supported the world's best facilities for aeronautical research. NASA's research centers also provide industry and the military with needed capacity for cost-effective central testing facilities for the development of aircraft and missiles.

Both industry and the military find the front end of the R&D process most difficult to justify—particularly applied research and fundamental technology development. Development-oriented organizations often find long-term investments in these early phases difficult to justify because the aircraft application is often not yet defined and the payoffs may be too unclear, risky, or far in the future.

Technology development is appropriate for NASA where the high risks, substantial costs, or long-term nature of a program cannot be justified by industry or the military services, in spite of potentially high payoffs. However, such excursions beyond research into technology development and costly, long-term, hardware construction and flight testing can also have negative impacts on NASA's broad-based applied research and generic technology development. In recommending a vigorous NASA flight research program, the White House Aeronautics Policy Review Committee also cautioned, as we have, that these activities ". . . must not overshadow NASA's creative, long-term aeronautical research, which is a high-priority NASA role.[6] All technology development programs, and particularly the costly System Technology Programs, should be examined very closely before they are initiated, because they tend to be demanding on NASA's limited aeronautical funds, manpower, and management attention. There must be particularly good fits between these programs and those that industry and the military would naturally undertake. Technology develoment is an area where development-oriented organizations are generally willing to commit considerable resources when the objectives seem sufficiently worthwhile.

We have recommended a more aggressive DoD experimental and prototype aircraft development program—within which NASA could play a major role. The best match occurs in technology demonstration, where the DoD develops the experimental aircraft, gains basic engineering experience, and obtains performance data, while NASA concentrates on extracting basic knowledge from the ground and flight tests. This division of responsibilities applies the best use of talents, distributes the costs, and maximizes the benefits of the program. Such programs should be conducted with the military concentrating on designs and technology that can evolve into military development aircrafts. NASA would not be the appropriate agency to lead an experimental aircraft program of this kind.

There may be exceptional cases, where a similar balance can be established with commercial firms. However, National Aeronautics Policy does not give NASA a primary role in technology demonstration, although the boundary between technology development and demonstration is not well defined. NASA's role in the development of particular technologies should be carefully assessed for each program. If the program is particularly appropriate for NASA, then limited flight testing may constitute a necessary portion of that program. We have recommended reinstating certain Systems Technology Programs in the NASA budget in each of the last two

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[6] "Report of the Aeronautical Policy Review Committee," (9 November 1983) conveyed with Memorandum from John McCarthy, subject, "Committee Report to Dr. Keyworth," Office of Science and Technology Policy, Executive Office of the President, Washington, D.C. (17 November 1983).

years because we believed that they were valuable and justifiable NASA program. In most cases, the programs that we recommended were funded by Congress. However, we must also caution that Systems Technology Programs and program management in NASA in general have an important air of visiblity, a base of advocacy, and an allure that could lead to a growth of such programs beyond the bounds that would represent wise investments of public funds or a proper balance for maintaining NASA's important output of broad-based applied research.

PROGRAM RECOMMENDATIONS

In general, we support the major thrusts and various program areas outlined in NASA's proposed fiscal year 1985 budget. However, we would like to discuss four main recommendations to provide a more agressive and properly balanced NASA aeronautics program.

(1) The funding and manpower for broad-based applied research and the associated general level of funding for the R&T base should be markedly increased.

(2) The budget for the Propfan Program should be increased sufficiently to include the planned flight tests of the 9-ft diameter, large-scale advanced propeller (LAP/PTA).

(3) Funding for current NASA research and technology programs related to high-performance military aircraft and helicopters should be increased during the period from fiscal year 1985 to fiscal year 1990, so that these NASA programs can influence the next generation of military tactical aircraft.

(4) The substantial increase in funding in fiscal year 1985 for multidisciplinary research is wise and should be continued to provide grants and contracts for research at universities. However, the methods used in conducting these programs must be improved to reap the multiple research and educational benefits possible from these investments.

Research and technology base

We recommend a marked increase in both the funding and the number of researchers assigned to aeronautical applied research within the R&T base. These increases in funding and manpower should be directed into the primary areas of aerodynamics, structures, propulsion, and flight controls and into methods for integrating these crucial areas. The increases should be distributed over a wide range of research topics in these primary fields and should not be channeled into a few areas in the R&T base that are already being vigorously pursued. We recommend a significant increase in supporting funds to operate and upgrade NASA's wind tunnels to increase the available capacity of these facilities. NASA should double or triple the flow of research data and new concepts for innovative aircraft configuration components, which are needed for superior aircraft designs. NASA should concentrate on hiring talented research engineers and scientists in the aeronautical field from universities and possibly even from industry, but should not retrain people already working in other areas inside or outside of NASA.

The R&T base provides the cutting edge of advancements for aeronautical designs. The R&T base provides the prediction methods, experimental data bases, knowledge, understanding, and creative innovations that lead to major advances in aeronautics. This is the most appropriate and highly productive NASA function in aeronautics. Most of the major advancements attributed to NACA and NASA came from R&T base activities, as for example, the supercritical wings, winglets, "coke-bottle" fuselage shapes, swept wings, advanced structural computer programs, aerodynamic paneling methods and so on. There has been a substantial shortfall in applied research results, particularly from NASA. The level of effort has been too low to provide industry and the military with sufficient methods, basic data, and fundamental advancements needed to continue to develop and produce superior aircraft. There is also an inadequcy in the level of aeronautical R&T being produced by military laboratories.

The NASA budget for the R&T base does not reflect the actual amount of applied research or fundamental technology underway in the program line items. A number of Systems Technology Programs were reduced by OMB and many were reportedly transferred by NASA to the R&T base in fiscal year 1983. Transferring these technology programs to the R&T base did not change the nature of the work. In the associated Congressional hearings, we warned that "the cancellation of high visibility systems technology programs and subsequent reassignments of portions of this work to the research and technology base may actually lead to undesirable decreases in high-priority R&T base work, even though the budget is increased in this

area." [7] This is exactly what happened. There was apparently a decrease in applied research in a number of areas to accommodate these Systems Technology Programs. Many of these technology programs were important, and we recommended that they be continued. Unfortunately, the program balance shifted, and other important applied research efforts were dropped without being apparent in the budget. Congress reduced R&T base funding by $12 million again in the fiscal year 1984 budget, and NASA also redistributed funds to focus on certain areas. This resulted in additional cuts in important long-term R&T base efforts, most of them in applied research.

We do not know the full extent to which NASA's creative applied research has given way to technology development programs as cuts have been administered, but it seems substantial. Let us examine some examples that you may be familiar with, because they have often been cited as important areas of NASA research. NACA and NASA provided industry with extensive data and made major advances in the critical areas of wing designs, such as the supercritical airfoil, the advanced general aviation airfoil, winglets, the cranked arrow wing, and host of high lift devices. Today, NASA's applied research on airfoil and wing configurations, particular experimental work, is meager by comparison with earlier years. Laminar wing research and wing blowing concepts for STOL seem to be the only areas receiving substantial attention. There is considerable emphasis on computational methods, which is important, but experimental configuration research and verification of the methods are still critically needed. NASA's applied research on aircraft configuration components in general is not as broad, systematic, or generally innovative as it once was. In propulsion, there have been major funding cuts in the R&T base programs applicable to increasing temperatures in the engine hot sections, which is essential to increasing the thrust and reducing the weight of future jet engines. These are just some examples of important areas where there appears to be a serious lack of emphasis and momentum in NASA's applied research.

Many problems must be addressed. Budgets for operating NASA's extensive wind tunnel facilities have not kept up with inflation and are not being fully used or are being closed to save money. The "greying of NASA" is taking its toll of top-quality research talent, while others seek the limelight of administration and contract management. There must be marked increase in the number of actual researchers and every effort must be made to have a highly talented and motivated research force. Personnel policies need to be examined to promote increased technical professionalism and to attract such people at the entry level.

The shortfall in applied research from NASA has been the subject of many prior recommendations by knowledgeable advisory groups dating back at least 10 years. A National Research Council report in 1981 concluded that "NACA" and NASA have many fundamental research contributions to aeronautics, and this storehouse of advances had been largely responsible for the nation's post-World War II success in aviation. However, there has been an erosion of NASA's research capability, particularly in manpower. This situation, if left unchecked, will surely have major ramifications. The technological capital accrued from past research investments will eventually be depleted. In the process, the center of gravity of aeronautical innovation may shift to Europe of Japan." [8] The National research Council study also pointed out the need to improve NASA's personnel policies.

NASA conducted a major study in 1976 dealing with the NASA role and future directions in aeronautics.[9] The study report stated, "It was the unanimous view of industry that NASA's role of supplying basic aeronautical R&T was the backbone of the aerospace industry in this country. Traditionally, NACA/NASA, through experimental and analytical research, provided the aviation industry with a data base of design information. The role of advancing the state of the art of aeronautics technology should be continued and expanded using a balance of in-house programs and contracted programs with industry. The NACA-conducted parametric wind tunnel tests and analyses provided an excellent technology base; however, experience in some segments of the industry with recent design programs has identified considerable gaps in the data base. It is believed that the data base has not been systematically maintained, and this is attributed to a significant period of minimal funding

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[7] "NASA Authorization for Fiscal Year 1983," Hearing before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science, and Transportation, United States Senate, Second Session, Serial No. 97-112, pp. 429 (23, 25 February; 16, 18, 30 March; and 1 April).

[8] "NASA's Role in Aeronautics: A workshop, Volume VI, Aeronautical Research," National Research Council, National Academy Press, Washington, D.C. (1981).

[9] "NASA Outlook for Aeronautics; The Outlook for Aeronautics 1980-2000. Appendix B, Study Group Report on an Industry-University Government Survey," NASA, National Technical Information Service, Springfield, Virginia (1976).

for aeronautical research. It is also felt that while technology demonstration (hardware) programs were valuable, the basic R&T has suffered as a result, and that a reemphasis on systematic parametric data acquisition and analytical technique verification is required." [9] In addition, NASA's own advisory groups have repeatedly made similar points extending back at least a decade.[10] [11]

If the government really wants to stimulate aeronautical innovations and new leaps forward in American aeronautics, major increases in applied research is the place to start.

Propfan program

We strongly recommend that Congress augment the NASA aeronautics budget to provide sufficient funding specifically for the Propfan Program to cover the planned flight tests of the large-scale advanced propeller LAP/PTA.

The propfan is an important and appropriate program for NASA to spearhead to a point where industry would naturally take over in its development. The propfan offers the potential of significantly reducing fuel consumption of civil transports, military transports, and possibly naval anti-submarine aircraft. What makes the Propfan special is that it can operate at cruising speeds approaching that of a pure jet. However, the potential payoff is very long term, and the risks are high. The propfan is a promising, but also a radical, innovation. The technology has been neither sufficiently developed nor tested to gain the acceptance necessary for the large investments it will require from the private sector.

A number of fundamental questions must be answered before industry would be willing to provide the full level of investment necessary to carry the propfan technology forward into development, develop the new engine that it would require, and also develop aircraft for this new propulsion concept. The main issues that must be resolved to a reasonable degree of assurance are:

(1) Will an aircraft with a high-speed propfan be acceptable from the standpoint of noise inside the aircraft?

(2) Can this very high-speed propeller be designed so that it is structurally safe? Can aeroelastic bending of the propeller be predicted, including flutter and divergence?

(3) Will there be adverse interactions between the propeller and the airframe? Can both the aerodynamic and structural interactions be adequately predicted for design purposes?

(4) Will the predicted propeller efficiency for the propfan be realized for the full-size installed propulsion system?

(6) Can a practical, reliable, and low-maintenance gear box be designed for a propfan?

Each issue represents a major technological gate through which the technology must pass before the propfan concepts move forward on their own momentum. NASA has been addressing all these major issues and others through analysis, component development, small-scale wind tunnel tests, and moderate-scale flight tests. The planned propfan large-scale flight test with a 9-ft propeller will provide answers to the first four major technological issues. The fifth issue regarding the gear box will be resolved by the planned full-scale ground tests using two different gear box designs.

The large-scale flight tests of the propfan will be accomplished by installing a 9-ft propeller on an existing aircraft. This is the maximum diameter and size propeller possible with an existing engine and is close enough to full size for reliable data. Full-size propfans would be about 10 to 12 ft in diameter. There have been many tests with a 2-ft propeller, but their validity as applied to a full-scale propeller is uncertain. Airlines in particular would not be willing to indorse a propfan engine or a related aircraft development programs without first having the results of such a large-scale test.

High-performance military aircraft and helicopters

Funding for current NASA programs applicable to advanced fighters and helicopters should also be increased during the period fiscal year 1985 to fiscal year 1990 to ensure that these programs will benefit the next generation of tactical aircraft. In other words, a surge of activity should begin now; efforts in these areas can be reduced in subsequent years. The emphasis should be on accelerating technological ad-

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[10] Minutes of the Meeting of NASA Aeronautical Research and Technology Advisory Committee (ARTAC) on Aeronautical Propulsion (24-25 April 1975).

[11] Minutes of the Meeting of NASA Aeronautical Research and Technology Advisory Committee on Aerodynamics and Configurations (25-27 July 1973).

vances for programs already underway and on developing necessary data bases for application of these advances to tactical fighter aircraft and helicopter designs.

The Air Force, Navy, and Army are initiating major programs this year for the next generation of tactical aircraft. The planned technology cutoff dates for these programs are between 1988 and 1990. Hence, the only way that important related NASA efforts can impact these programs is to produce their results prior to these dates. The military development programs that will benefit from these NASA programs include:

Service	Aircraft
Air force	Advanced tactical fighter (ATF).
Navy	Advanced tactical aircraft (ATA).
Army	Light attack and utility helicopter (LHX).

The aircraft and their design requirements are currently being defined through extensive military and industry studies.

The designs of these new advanced tactical aircraft, both fighters and helicopters, can be greatly improved by many applied research and technology programs currently underway in NASA laboratories and under contract. Important R&T areas include improved wing configurations, innovative aircraft/propulsion integration methods, high-angle-of-attack aerodynamics, advanced augmented lift methods, composite structures, aerolastic tailoring, advanced flight controls, and stores carriage and separation. Some applicable technology demonstration programs in advanced stages are being jointly conducted with the military services, namely the X-29 Advanced Technologies Demonstrator (DARPA/USAF) and AFTI-16 (USAF). It is extremely important to accelerate appropriate programs, as necessary, to meet the service's technology cutoff dates. Otherwise, potentially valuable technological advances will not be designed into these aircraft and a considerable amount of NASA time, funds, and effort might not pay off when it is needed.

Multidisciplinary research

The fiscal year 1985 budget for multidisciplinary research grants and contracts to universities provides a funding level twice as great as fiscal year 1984, but about 60 percent below the fiscal year 1982 expenditures corrected for inflation. NASA funding for universities under this program and other R&T programs is wise, because it can provide low-cost aeronautical research and also advanced aeronautical education. However, we recommend that NASA make two main improvements in the methods used for providing support under many of these programs, particularly under multidisciplinary research programs: The program at universities should be planned on a multiyear basis, because of the time it takes to conduct basic research and the critical importance of providing stable support for university faculty and students. The majority of research should be done at the universities rather than removing graduate students or faculty to NASA centers.

It is just as important to produce enough good engineers and scientists to absorb, use, and expand on research and technology as it is to generate it. Fortunately, it is possible to accomplish both objectives with a single mechanism. Government research grants and contracts have a multiple payoff; they provide: Aeronautical research at low cost; Financial support and challenging research work for teachers; Financial support for graduate students and expsoure to important problems; and badly needed modern facilities for research and teaching.

These objectives cannot be accomplished if the universities cannot plan more than a year ahead for student or faculty support. Many NASA grants and contracts to universities last for only one year. Significant research problems and the related Ph.D. education programs usually take two to four years to complete. It is quite a problem for a university to accomplish its education and research goals when it cannot count on more than one year of support on a given problem.

In addition, the expected multiple objectives to be gained from NASA support to universities will not be accomplished if either the students or the faculty are removed from the universities to NASA centers for long periods of time. Many NASA grants and contracts operate this way. There must be continual three-way contact among faculty, students, and available facilities at the universities to provide the multiple payoff we have described. At times, students and faculty can realize substantial benefits by visiting NASA centers for periods of time to utilize major NASA

facilities in conducting portions of their research work. However, more of the NASA-sponsored university aeronautical research should be done at the universities.

CONCLUDING REMARKS

We strongly endorse the NASA aeronautics program and are encouraged that the aeronautics budget is beginning to reflect improvements that are consistent with the National Aeronautics Policy. The establishment of the White House Aeronautics Policy Review Committee and their first report are hopeful signs that this important policy will be implemented. However, there is still a long way to go before we will witness a reversal in the negative trends that have built up, for some time, from a lack of emphasis on aeronautics. There must be further improvements in both the pace of the nation's aeronautical R&D activities and also in the manner of conducting them. If it is to be "business as usual," it stands to reason that we can expect the trends of the past to continue.

In prior testimony, we proposed an eight-point program to achieve this nation's aeronautics goals. Some progress has been made along these lines. Today, we have offered four recommendations for improvements in the NASA aeronautics program. Not all of these changes may be possible this year, but next year's programs could fully reflect them.

Thank you for the opportunity to appear here today and to express our opinions freely on these important issues.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORTON AND THE ANSWERS THERETO

Question. Mr. Album, in your testimony, you have inferred that for NASA there is a grey area between technology development and technology demonstration and that, where "appropriate," NASA should perform limited flight tests.

(*a*) Generally, what would constitute "appropriateness" for NASA to conduct flight-test programs to validate a particular technology?

(*b*) Are there technologies for which NASA should be conducting flight-test programs but is not?

Answer. NASA should continue to support technology demonstration programs by the military services. These should be highly advanced programs where NASA concentrates on and extracts experimental data and conducts analyses of broad research value, while the military services basically develop the test aircraft and focus on obtaining overall flight performance characteristics of greatest interet for future military applications. The great balance of the investment and planning of these technology demonstration programs, particularly the hardware definition and contracting effects, should be heavily weighted to fall under the DoD—otherwise, one would have to question the real value of the program to the DoD. These efforts should be true cooperative programs with substantial joint participation by the military services and NASA at all stages of the program, particularly the test program, so that the results will rapidly impact military aircraft development programs, as well has provide potential spin-offs for civil technology. The idea of NASA generating programs of this sort with large investments of primarily NASA funds and manpower—merely "coordinating" these efforts with the military services—would not be appropriate. One would have to doubt the real value of such programs to the military, without their investment in it, no matter what was said. There would be a serious question as the advisability of such a reversal in roles.

The question of "appropriateness" becomes far more difficult to answer categorically for an expensive hardware technology and flight test demonstration program where a high payoff to civil aeronautics is the driving force. The justification is greater if there is also a potential military payoff. Hwever, it is still difficult to gauge whether it is an appropriate NASA program as opposed to leaving it to industry or the military to fund. There are six questions that all must be answered positively to consider such a program appropriate for NASA:

(1) Does the technology advancement appear to be credible and have sufficient predictive methods been developed from theoretical analyses and small-scale experiments? In other words, has the technology been brought to the point where large-scale flight testing is the next logical and necessary step in its development?

(2) Does the technology promise exceptionally great improvements in aeronautical capabilities relative to the program's cost?

(3) Does it appear to the potential users that if the planned flight test program is successful, the technology will have enough momentum from that point forward to eventually be used in a civil (or military) aircraft?

(4) Do the risks, time period, and comparitive investments required place this program beyond what industry (or the military services) could justify at this stage?

(5) Are the total NASA program costs in laboratory and contract funds a small percentage of the cost of the follow-on technology and product development programs expected to be funded by industry (or the military)?

(6) Does NASA have the necessary special expertise, facilities, resources, and knowledge to manage and/or conduct the program?

In fact, these same questions hold true for all NASA technology demonstration programs, civil and military. In all cases, it is also important to ensure that these flight test and demonstration programs, which fall in the later stages of technology development, do not become such a large part of NASA's programs that they materially cut the vital sources of new technology and innovation that flow from NASA's applied research programs.

In my view, NASA has some highly innovative flight test programs planned and under way in the fighter technology, helicopter technology, STOL, and subsonic transport structures. We strongly advocated the planned propfan (LAP/PTA) flight test program. In addition, advanced technology flight test programs are under way and should probably be expanded for general aviation aircraft. However, considering NASA's flight testing funds, facilities, and manpower, there does not appear to be any point in discussing more flight test programs without a willingness to add all the funds and people necessary to conduct these flight demonstration programs. The alternative would be to further reduce NASA's applied research which, without doubt, will be reflected dramatically in our relative rate of progress in the future.

Question. Mr. Album, in the late 1970s, Japan emerged as a challenger to the U.S. in the development of ceramic heat engine technology. Recognizing that the high-risk/long-term payoff of ceramics technology may preclude U.S. industries from currently investing adequate resources, what should be the role of NASA in developing advanced ceramic heat engine technology?

Answer. We believe that NASA should stress applied research and generic technology on engine hot sections. This includes investigations of ceramic materials for these engines. In addition to jet engine applications, ceramic materials may lead to diesel engines of reasonable weight and reduced costs for general aviation aircraft. Last year's cut in the R&T base materially impacted NASA's program on engine hot sections. NASA should pursue the ceramic engine technology program through applied research, small component design, critical ground tests, and, possibly, beyond into flight tests in the case of an all-new engine such as the diesel engine. Ceramic materials are a relatively high-risk technology and present some difficult problems.

Question. Mr. Album, the Administration's Aeronautical Research and Technology Policy of 1982 recommended that "NASA and DoD encourage the transfer of aeronautical research results to and within U.S. industry."

(*a*) Is private industry receiving in a timely manner the research results of NASA and DoD?

(*b*) Is there an appropriate transfer of technology between NASA and DoD?

Answer. The transfer of aeronautical research results in published form is about as timely as can be expected taking into account NASA's recent efforts to provide early results. NASA has particularly been trying to increase the timelessness of information from its flight test programs. There are many acts of cooperation and interchanges of information that one could cite and NASA has been an agency strongly oriented to both cooperation and information transfer. More could be done by the government along the lines of person-to-person consulting for industry in helping to apply the research results. Travel funds would help in this regard.

The transfer of technology from DoD and NASA contracts is a difficult job which neither agency has managed to master. The mechanism is usually to have a number of published reports and, in some cases, to give one or two briefings to large audiences. Most technology programs do not allow enough manpower or funds to transfer results out of the program. Even, though the government funds a contractor to develop a technology for national use, there is a natural reluctance on the part of every manufacturer when it comes to providing that technology to its competitors. In addition, the pure mechanisms for tranferring information are difficult. It takes special measures to ensure that there is, in fact, a meaningful transfer of technology out of government contracts with manufacturers.

However, it is possible to make gains in this area. One of the best ways is through personal contacts. Under DARPA, for example, there is a group called the Future

Applications Committee for the X-29 Advanced Technologies Demonstrator. The X-29 is an experimental aircraft under a joint DARPA, USAF, and NASA program. This committee consists of vice presidents of engineering, heads of advanced design, and directors of technology from industry and leaders in technology and requirement from the Air Force and the Navy. There are only about 25 people on the committee. This group has regularly followed the X-29 program for two years, through all major problems as they occurred and the solutions. Specialist groups review details of critical technologies and related solutions to design problems. The Future Applications Committee played the major role in defining and setting priorities for data for the X-29 flight test program to be conducted by NASA. The key here is close personal contact with the program as it progresses.

Obviously, there can not be a Future Applications Committee for hundreds of technology programs because the aeronautical leaders of this nation would have little time for anything else. However, we have advocated the establishment of national technical committees in aeronautics for joint consultations on programs and future planning among leaders in all sectors of aeronautical R&D. These committees could, over time, go a long way to aid in the transfer of major advancements in research and technology among all segments of American aeronautics. Foreign nations may have access to our unclassified literature, but do not have ready access to the people behind our advancements and the knowledge and understanding that they possess. We need to make better use of these human resources.

Question. Mr. Album, in your testimony, you have stated that technical subcommittees similar to those that existed under the NACA should be established to maximize our nation's aeronautical R&T efforts.

(*a*) What advantages would these technical subcommittees offer over the current organizational structure within NASA and, in your opinion, why have they not been established?

Answer. The national technical subcommittees that we proposed would consist of leaders from all sectors of aeronautics within particular discipline areas. The members would have equal status on the subcommittees, including technical leaders from NASA. The subcommittees would periodically convene for joint confidential consultations on advancements made by their groups, problems encountered, programs, and future plans. They would set courses of action on problems of mutual concern, stimulate cooperative programs, and divide tasks when they think it appropriate.

I believe that this would help maximize our national R&T efforts. It would provide a transfer of information, technology, and cooperation across organizational and sector boundaries. The personal relations and natural cooperation that would develop among groups in aeronautical R&T would strengthen our national thrusts in all sectors.

These would be national groups that NASA would participate in—but they probably could not be a part of NASA as they were for the NACA. The old NACA technical subcommittees were a parallel committee structure that existed alongside the NACA administration and laboratory system. These technical subcommittees were headed by a governing executive board, with members from all sectors of aeronautics. This was also the board of directors for the entire NACA administration and laboratory system. Such a system would be difficult to duplicate today, because NASA also has an independent space mission. NASA has advisory committees from all sectors of aeronautics which do serve the agency as outside review bodies for NASA's proposed programs, but without that board of directors. These NASA advisory group do not provide the national consultation and coordination functions that I have described.

NASA does a great deal to cooperate and coordinate with various industry and military groups through a huge number of individual contacts and, also, group efforts. The military likewise has a very large number of such individual contacts and many joint programs. The American Institute of Aeronautics and Astronautics holds meetings and publishes journals to promote the transfer of information in our field. This proposal for national technical committees is not meant to critize these efforts. They are all valuable and should continue.

However, what is clearly missing are national technical committees where leaders in prime technical disciplines periodically sit down around the same table and discuss major technical problems of mutual concern across the board. The environment should be voluntary, nonthreatening, and natural. Where competition among companies becomes a barrier then special methods can be set up for government leaders to review different company positions in confidence.

The proposed national technical subcommittee structure might be established in a number of ways, such as:

Under the National Aeronautics Policy Review Committee for the White House.

On a rotating basis among government agencies: NASA, Air Force, Navy, and Army. Every two years the overall chairmanship might switch from one agency to another.

As a joint committee structure that might be set up among all government agencies similar to the NASA–DoD Aeronautics and Astronautics Coordinating Board (AACB), but including members of all sectors of American aeronautics as peers. The AACB is a DoD–NASA coordinating group and a national group might not fit well directly under this existing structure.

National technical subcommittees in aeronautics no longer exist today because we simply cut the links when the NACA was terminated. NASA was no longer purely a national aeronautics service agency because of its independent space mission. In fact, the Space Act of 1958 removed the roles for national advice and coordination for aeronautics that were assigned to the NACA by law. The interlocking board of directors approach did not fit NASA and, as an independent agency, it did not make a natural host organization for such a nationally-oriented set of technical subcommittees. In fact, there may be concerns today on the part of some government groups that there will be a loss of autonomy and perhaps even outside domination if attempts are made to run such a national committee structure solely under any one agency. A few elements in the private sector might also fear a potential loss of individual influence in dealing with the government from such a broad base of inputs that would naturally occur within such a national technical committee structure. However, we strongly advise that these national committees be set up again to better marshall our technical efforts in American aeronautics.

Question. Mr. Album, in your testimony, you have recommended a significant increase in supporting funds to operate NASA's wind tunnels to increase the available capacity of these facilities. Since, as I understand, NASA does not charge other government agencies, including DoD, or joint projects involving NASA for wind tunnel use, is this a policy that warrants re-evaluation?

Answer. The NASA facilities provide a dual function in their capacity to conduct research and to support tests for other government agencies. Often, these are joint programs in which there is a natural division of funds, work, and test support. There would be no more sense in NASA charging its partner in a joint program for this test support than for the other agency to change NASA for the manpower test and contract reports resulting from the partner's portion of the program. Hence, there is no question that it would not be appropriate for NASA to charge for contributing the testing portions of joint R&T programs.

NASA is often approached to conduct R&T tests for the DoD that will result in data of substantial research value in NASA programs as well. The DoD supplies the wind tunnel models and helps run tests; the data goes to both the NASA and the military services. This becomes a cooperative program, and falls into the previous category for which a testing charge does not seem justified.

At times, the DoD requests NASA to conduct wind tunnel test of aircraft configurations and components needed for DoD development programs. The NASA tunnels provide a national surge capability for such testing and sometimes the NASA tunnels may be the only correct tunnels available for the tests at the time. These tests may produce data of value to NASA research and NASA engineers may contribute to the solution of development problems. However, the real value to the country is the availability of these NASA tunnels for the tests at the particular times that they are needed for these military development programs.

The question than is whether it would be a good management practice for NASA to charge the DoD for these development tests. In trying to answer this question, we must consider the reason for the existence of aeronautical activities in NASA. In aeronautics, NASA is a service agency to other government agencies and to industry. NASA has no prime mission of its own in aeronautics, and thus the funds provided to NASA are to peform services. The testing of aircraft models in the wind tunnels for DoD or FAA programs clearly is a service. It would be just as reasonable for NASA to charge for these wind tunnel tests as it would be for NASA to charge for consulting manpower, flight simulations, computer calculations, or anything else that NASA might do to assist the DoD to successfully complete a defense development program. Hence, we are not just considering wind tunnel tests; we are considering all DoD development program support.

The result of a policy for NASA to charge for assistance on development programs would be a reduction in NASA assistance to the DoD on these programs, less NASA familiarity with real development problems on advanced aircraft, decreased utilitization of the federal investment in NASA's advanced facilities, and a decrease in needed tests for military aircraft development programs. On the other hand, there

would probably be an increase in funds to operate NASA facilities for research and technology work, but the funds would come from the same federal treasury.

Overall, I believe that the net effect will serve to separate NASA further from important DoD development problems, when efforts should be made to increase the use of NASA talent for consulting on important development problems. This is technology transfer in its highest form. It provides us a marked advantage over our foreign competition. They can only read publications by these people and they do not have access to these research facilities for their development programs.

Question. Mr. Album, NASA has been jointly participating with DoD in the JVX tilt-rotor program and in the X-wing rotor program.

(*a*) What are the commercial ramifications of these two programs, and have the costs and responsibilities been appropriately shared between NASA and DoD?

Answer. In my opinion, the XV-15 program that led to the JVX tilt-rotor program has been one of the most successful joint technology demonstration programs ever conducted between the DoD and NASA. The degree of cooperation and integration of efforts on this program was remarkable. The Army provided the early leadership in defining the program but there was NASA and Army participation at all stages. The funding for the program was divided fifty-fifty between the two agencies and the manpower on the program was divided in about the same proportion. The geographic location of the Army laboratory and the headquarters of the Army aviation laboratories at NASA-Ames had a great deal to do with the excellent integration of efforts of that program there. The division of funding and manpower was about the maximum percentage that I believe NASA should ever put in to a DoD technology demonstration program.

NASA is supporting the X-wing program, which are joint programs with DARPA. The NASA support is primarily for flight tests of the rotor system on a NASA research vehicle designed for that purpose. NASA has also supplied wind tunnel testing and other types of analytical support. DARPA is developing the rotor systems and associated hardware at considerably greater cost than the NASA investment. Thus, DARPA is developing the hardware and NASA is concentrating on getting the flight research data results. This seems to be a proper division of both funding and responsibilities for a joint NASA-DoD program.

The XV-15 program certainly does have potential commercial ramifications. The XV-15 has the capabilities of both a helicopter for takeoff and landing and a fixed-wing aircraft for long range flight. A commercial version of the tilt-wing may result from the JVX program. Such a commercial tilt-rotor aircraft could have applications for offshore oil rigs, which are being placed further and further out to sea. There would be a market for such an aircraft in underdeveloped areas such as Alaska where the population centers are far apart and runways are expensive. There also may eventually be executive versions of the tilt-rotor aircraft.

However, tilt-rotor aircraft will generally be more expensive than either pure helicopters or fixed-wing aircraft. They will fit in special market notches that require the capabilities of both of these aircraft in a single vehicle. That market obviously does not appear big enough for Bell to develop a commercial tilt-rotor aircraft solely with private capital. The JVX program could make a big difference in what happens along these lines.

The X-wing is a more advanced concept than the tilt-rotor and promises increased performance. It is much further off in time in terms of application. The technical risks are also higher than for the tilt-rotor at the current time. The X-wing may also have commercial applications for the same reasons as those described for the tilt-rotor.

Questions of Senator Heflin and the Answers Thereto

Question 1. At the hearing, your comments indicated that you were generally content with the President's 1985 budget request for NASA's aeronautical R&D programs. Is that correct? If not, what specific changes would you recommend to the Committee?

Answer. We basically endorsed the general thrusts of NASA's proposed fiscal year 1985 aeronautics program. We were glad to note a substantial increase in the total budget for fiscal year 1985. However, when one examines the specific program areas, there appear to be very substantial deficiencies in funding. These areas include the important propfan flight test program for the 9-ft propeller under LAP/PTA program. In addition, in our submitted statement we cited the substantial deficiencies in NASA's applied research program, including work aimed at engine hot sections which is needed to increase the efficiency and reduce the weight of ad-

vanced jet engines. We cited the need to increase applied research on innovative aircraft configuration components and designs, particularly work on wings. Wind-tunnel funding must be increased both to upgrade the experimental capabilities of existing tunnels (e.g., advanced instrumentation), and also to operate them. We stressed the importance of accelerating work applicable to tactical high performance aircraft and helicopters at this time. These important needs can only be appropriately met by providing an increase in funding for NASA's aeronautics projects. In particular, Congress should consider augmenting the NASA budget to carry out the planned 9-ft propeller of propfan flight test program to keep this program on schedule.

Question 2. Your testimony focused on the need for higher levels of basic research through an increased Research and Technology Base. What do you believe to be the appropriate balance between NASA's R&T Base programs and the applied Systems Technology programs?

Answer. This is an excellent question. However, I am not in a position to provide you a specific answer. My committee did not address this issue to this degree. It would require some study.

However, I would like to make it clear that we advocated substantial increases in NASA's efforts in applied research. Applied research focuses on gaining knowledge and developing innovative methods in areas where there appears to be advances possible and a class of important applications for those advances. Basic research is more fundamental. It develops a broad base of knowledge that can be of great value, but the applications are not the driving force. The analogy that I used in referring to Einstein, who conducted basic research, was meant to make the point that theoretical and laboratory experimental work in the early stages of R&D are extremely important to what happens in the end. The low costs are not a measure of the importance nor is the low public visibility of the work as it proceeds. We see the results years later in the final product.

Question 3. You also discussed the need for increased funding in 1985 for the Advanced Turboprop Porgram. If the Committee chooses to increase funding for the ATP, especially to ensure the 1987 flight test, what areas do you think we should consider as possibilities for offsetting reductions?

Answer. I am not in a position to respond to this question either. My committee did not address this issue. I do not believe that it would be correct for me, under the circumstances, to offer my personal opinion on specific programs' relative priorities.

Question 4. There is always a great deal of discussion in the aeronautics program as to how much private sector involvement there is and whether more is needed. How can NASA encourage more private sector competition in its aeronautical R&D programs?

Answer. We believe that NASA does encourage private sector competition in its aeronautical R&D programs. In our view, NASA should always pick the best contractor for the job and then make sure that the results of each program are made available to all competing companies. This requires that NASA devote a reasonable percentage of the funds for each program to ensuring absolutely that there is a transfer of experience, knowledge, and information out of each program to all potential users.

Question 5. We are told that the U.S. must stay on course with the Advanced Turboprop Program in order that our aircraft manufacturers will remain competitive in the 1990's and 2000. To what extent are foreign governments and manufacturers involved in developing advanced turboprop technology and how far along are they?

Answer. The French, British, Japanese, and Russians are all working on the propfan. They are primarily engaged in small-scale testing at the current time and the indications are that there are substantial efforts behind these programs. The French, for example, have the best available wind tunnel for testing large size propfans at speed conditions equal to today's jet transports. In fact, Hamilton Standard plans to conduct its wind tunnel test on the large scale propfan in a French wind tunnel because we have no wind tunnel in this country for testing such advanced turboprop propellers under these conditions. This wind tunnel will give the French quite an advantage in developing advanced turboprops.

In general, we have a reasonably good lead, perhaps several years, over the foreign competition at the current time. A lead of three years in sales of a new aircraft would be a substantial lead for capturing the market. However, the submitted NASA budget for the propfan program would result in about a one-and-a-half-year delay in flight testing our propfan. It is important to provide a fully-funded propfan program to keep it on schedule.

Question 6. What are U.S. manufacturers doing in preparation for the ultimate development and refinement of the advanced turboprop technology?

Answer. There have been many studies conducted by military and civil transport manufacturers of advanced turboprop aircraft designs. Certain general aviation manufacturers have also been studying the application of advanced turboprops to new designs. Engine manufacturers have been evaluating the engines that could be used for advanced turboprops. The basic propfan for transport aircraft would be between 10 and 12 ft in diameter and would require a new engine. Although this engine has been under study, no company would undertake a complete development program of such an engine, which might cost up to a billion dollars, until the feasibility of the propfan can be evaluated from the planned NASA flight test program.

Question 7. A great deal of concern has been raised about the future of propulsion programs at NASA after the Energy Efficient Engine (E^3) program. What do you think would be an appropriate propulsion initiative for NASA after the E^3?

Answer. NASA should be conducting applied research and limited component technology development aimed at the next generation of large turbofan engines. We agree with the Aircraft Industry Association's testimony that large turbofan engines will be the primary propulsion mode for transport aircraft and will constitute the bulk of the transport aircraft engine market. Many of the programs that were cut in the R&T base last year in reprogramming by NASA to accommodate the propfan program were important for all future jet engines, incuding those for large turbofans, turbojects, and even engines that must be developed in the future for propfans. We believe that these efforts should be restored and increased to provide for the next generation of jet engines. There shold also be technology programs specifically aimed at the next generation of adanced large turbofan engines. These programs should constitute a reasonably-sized effort at this point supported by increments in the NASA budget, not redistribution of funds from other areas.

Senator GORTON. Dr. Harr.

Mr. HARR. Thank you, Mr. Chairman. I, too, with your permission, will summarize my statement.

Senator GORTON. Your entire statement will be included in the record.

Mr. HARR. Thank you, sir.

I am president of the Aerospace Industries Association, the trade association representing the Nation's major manufacturers of commercial, military, and business aircraft, helicopters, aircraft engines, missiles, spacecraft, and related component and equipment. As you announced at the opening, Mr. Chairman, accompanying me is Mr. James N. Krebs, vice president and general manager of the General Electric Co.'s military and small commercial engine operations.

I read through that first paragraph because I want to make clear that we are a trade association, as distinct from our distinguished professional colleagues who have just testified. We come at these problems from the point of view of the business of the industry pretty much, and this hearing is most timely.

Perhaps there has never been a more important watershed time for this kind of look at NASA's AR&D budget. The OSTP report in 1982, the policy review committee report, what NASA is now trying to do to increase its aeronautical R&D, and the attitude about it, make this all a very timely time to get right down and look at it.

And we have an added starter on that, too, which we think is important, Mr. Chairman. We have our own report which came out a few months ago and which we have been distributing to key decisionmakers, first primarily in the executive branch but now also we want to come to you and peddle our wares. It is called trade and R&D policies, an aerospace industries association proposal. And we have provided copies of it to all the members of the com-

mittee. And there are some more here if anyone wants to take them off the table.

Given so much previous testimony from the technical and scientific analysts from both within and outside Government, from the NASA managers, the DOD managers, and congressional staffs and everybody else on the technical aspects of the problem we all see, we think it perhaps important to inject an industry, business-oriented perspective because it comes at the problem from a slightly different angle.

Our proposal is the product, incredibly, of 50 major companies agreeing to put out and stand behind a piece of paper which details their best analysis of what the United States has to do to reverse some of the adverse trends that have become so apparent in the past few years.

What we see is very close to what you described in your opening statement, Senator, and what Mr. Album has said. We see a competitive situation deteriorating, a trade deficit growing at an alarming rate, and the closing of the technological gap between the rest of the world and ourselves, a gap that we have enjoyed through most of our 20th century history, or at least the post-World War II history.

I think it is important to say why should it not close. Our European and Japanese trading partners have the appetites, they have the brains, and they have the aerospace work force with its talents and its need to be employed for political reasons at home. They want to get in the high technology global industry of aerospace in a major way, and they are doing so.

And I do not think there is any mystery about it. They solved the problems of recovering from World War II quite a while ago. They have solved a lot of problems of working together across national boundaries that they had never been able to do before in their history, and they have a formidable technology base for competition, and they want it. They want to succeed.

Well, that is the situation. We have been to some degree over the past 5 to 10 years resting on our oars, with barely adequate R&D support and totally inadequate trade policies. Now what our document tries to say is that solutions do not lie in negativism, protectionism, piecemeal remedies, or putting band-aids on wounds.

They lie in building on our own strengths, and our proposition is a simple one but we think it is so important it be accepted that I would just like to spend a minute or two on it. We still have the best national industrial and economic base for trade of any country in the world. We still have the greatest core and depth and breadth of capacity for research and development and the exploitation of that research and development.

Our point is that the two are inextricably linked—not a very startling conclusion, but I think a very important one. Without an upgrading of our national trade policies we are not going to sell in today's competitive market even with equal or slightly better technological superiority of our products. And, conversely, unless we have superior technological products we are not going to sell without a substantial upgrading of our national trade policy.

So we have listed all of the kinds of things that lie in current legislation, lie in future legislation, lie in the policies of the execu-

tive branch—Treasury, State, Commerce, USTR—that need upgrading if we are to unfetter the strength of American industry and American technological know-how. We have recommended a number of specific steps with regard to both trade and R&D policies to accomplish that end.

Now that is down the road. As far as the aerospace industry is concerned, we are doing pretty well now in most of our areas. Our overall sales are high, and they should reach $82.5 billion in 1984. Our net exports are the largest of any manufacturing industry in the country, by far. The aerospace international trade balance in 1981 and 1982 registered $13.1 and $11 billion, respectively. Last year, when the Nation as a whole incurred a trade deficit of $60 billion, the aerospace industry again rang up a surplus of $12.6 billion.

But even though the aerospace industry is one of those who is doing relatively well, the trends are ominous. We have all discussed those. I will not take too much time. They do not need much spelling out.

So in this formula all aspects of R&D promotion are important—tax incentives, recognition of the high R&D payoffs, collaboration with universities, everything that would upgrade U.S. technology. But aeronautical research and technology occupies a special and distinct niche, because that is where today and all the way back to NACA the rabbit that will be pulled out tomorrow was put into the hat, and that is what we are really talking about today.

The details of it, of course, can be argued in terms of priorities, but the fact is 10 years from now, 20 years from now, if we have not put enough of the right rabbits into the hat we will not be able to pull them out in a world where everyone else has put their rabbits into the hat.

So, as I said before, in the context of our overall view of the situation these are perhaps the most important hearings that have ever held on this subject.

High technical, high unit cost products such as aircraft are the lifeblood of our international marketing position. The keels of the ones we will have tomorrow are being laid in NASA's R&D budget today. Against that background the message again is that there is a very obvious and vital linkage between upgrading national trade policies and upgrading our national R&D policies, and that is our message.

Our board of governors decided that we should go and sell that to the world. Who are we to sell it? Who is any industry to sell it? Well, we are one of the top high tech industries. We are the largest exporter. We are doing pretty well. But, as I say, the trends are not what we want to see and bode trouble for the future.

Having accepted that proposition, the board of governors of AIA authorized our technical council to proceed with a study about technology for the 1990s, what it would look like, what was desirable, what was achieveable. And, if I may, Mr. Chairman, I would like to turn that part of the discussion over to my distinguished colleague, Jim Krebs.

[The statement follows:]

STATEMENT OF KARL G. HARR, JR., PRESIDENT, AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

Mr. Chairman and members of the subcommittee, I am Karl G. Harr, Jr., president of the Aerospace Industries Association of America, Inc. (AIA), the trade association representing the nation's major manufacturers of commercial, military and business aircraft, helicopters, aircraft engines, missiles, spacecraft and related components and equipment. Acccompanying me is Mr. James N. Krebs, Vice President and General Manager of the General Electric Company's Military and Small Commercial Engine Operations.

AIA appreciate the Subcommittee's invitation to appear here today to present our comments on the proposed fiscal year 1985 NASA budget. Your letter of invitation specifically solicited our evaluation of whether the requested funding for the aeronautics-related portion of the budget is consistent with the goal of maintaining the United States' role as a leader in aeronautical science and technolgy—a goal enunciated by Congress in the 1958 National Aeronautics and Space Act.

The Subcommittee's invitation is a particularly timely one, as AIA has recently released a report—copies of which have been provided to the Subcommitte—entitled "Trade and R&D Policies: An Aerospace Industries Association Proposal." This report was developed by the Association's Board of Governors, and represents a major review and assessment of the critical problems facing the United States in the international marketplace. I propose to present a brief overview of the origins of this study, as well as highlight the key points of a complementary AIA report entitled, "Aerospace Technology for the 1990s." The latter paper details an intensified R&D effort concentrated on certain technologies that offer the potential for large improvements in the cost and performance of future aerospace products, and hence, promise the highest payoff for national defense and the competitiveness of the U.S. aerospace industry. My remarks will, however, be confined to the aeronautical portions of that report.

For a good part of the twentieth century, the United States was the acknowledged world technology leader. This technological superiority enabled the United States to offer better products at lower prices, and this secured American pre-eminence in the global marketplace—and greatly contributed to a strong economy.

As you are aware, that picture has changed dramatically in the last twenty years; today, the United States is confronted with an international trade challenge of unprecedented dimension. Our foreign competitors have invested years of effort in upgrading their technological in industrial capabilities, and their governments have further enhanced their improved technological postures by providing an array of trade-enhancing support mechanisms, ranging from development subsidies and tax incentives to financial assistance in marketing.

Thus, the challenge from abroad is two-pronged: a technolgical challenge that is likly to intensify as foreign competitors seek to broaden their share of the global market by furthering their technical competence in other areas, and the non-technical challenge presented by foreign governments' support of their exporting industries. While we fully support our government's continued efforts to negotiate a more equitable trading environment, it would be unrealistic—and naive—to expect that we can negotiate out of existence the advantages our foreign competitors enjoy.

Clearly, it is time for a strong American response—a two-pronged response to a two-pronged challenge. The United States must develop countermeasures to neutralize, to the degree possible, the competitive advantages accruing to foreign manufacturers as a consequence of their governments' support. However, given the fundamental differences between the United States and foreign economic and political systems, we cannot expect that the U.S. government can or will provide American export industries with the same type or extent of support available to our foreign competitors.

Therefore, AIA believes that the best opportunity for reversing the current trend in international trade lies in bold, innovative technology thrusts that will yield products of indisputable technical and economic excellence—products whose qualities outweigh whatever non-technical marketing attractions our foreign competitors may offer, and so recapture a larger international sales volume for the United States.

These goals are within our nation's reach, and they must be accomplished. The United States has not lost its technological capability—only its margin of technical superiority in some very key areas. Regaining clear-cut technical superiority requires that the Administration, the Congress and the American people recognize that U.S. preeminence in science and technology is of paramount importance to the nation's economy, its security and its standard of living. There is a parallel need for

a comprehensive government policy concerning the conduct of industrial research and development; a policy that accords a higher national priority to R&D; that encourages more effective cooperation among government, industry and the academic community; and one that stimulates industrial R&D aimed at the creation of superior products for the marketplace.

With regard to aerospace, AIA has emphasized revitalizing U.S. competitiveness in this industrial sector through new, focused technology thrusts for the 1990s. Our proposed strategy centers on an intensified research and development (R&D) effort directed to certain technologies with the potential for substantial improvements in the cost and performance of future aerospace products—technologies which promise the highest payoffs for both national defense and the enhancement of the industry's international competitiveness.

While we recognize that revitalization of the U.S. international trade posture will require new trajectories of technological progress in many product groups, we believe that aerospace merits special attention in view of its wide-ranging importance to the nation in the areas of national security, transportation, communications, science and technology, and the overall national economy.

The criticality of this industry was importantly acknowledged in the Office of Science and Technology Policy's (OSTP) 1982 report on aeronautical research and technology (R&D). That study confirmed what the aerospace industry has always known—that a superior aeronautics capability is a unique and vital national asset, and that the foreign challenge to this capability deserves serious national attention. Witness the quantifiable payoffs of an American aerospace industry that, while buffeted by government-subsidized foreign competition, has remained committed to preserving the technological edge: in 1983, when the nation as a whole experienced a record international trade deficit, the aerospace industry rang up a solid trade surplus of nearly $13 billion—thus offsetting to a substantial degree the deficits in other industrial sectors.

While evolutionary improvements to products of the 1981s will extend sales of some items into the 1990s, all aircraft operating today will be obsolete by the year 2000. Thus, the only real solution to the long-run problem is development in the 1980s of high-payoff, advanced technology that can be incorporated into new products for the 1990s. If the U.S. aerospace industry is to retain or re-establish dominant product superiority in the international marketplace, there must first be a commitment to a program of focused technology development with cost superiority and an emphasis on designing to cost, advanced manufacturing technology, increased factory productivity and a better-motivated work-force—management challenges the industry must resolve to meet.

When the AIA Board of Governors completed the "Trade and R&D Policy" paper it asked AIA's senior technical body what could be accomplished in an environment characterized by greater industry/government cooperation, where industry would be provided with broad R&D incentives. Their response was the report, "Aerospace Technology for the 1990s." Built upon other important studies—including the 1982 OSTP report and DARPA's look at 17 key technologies—the "Tech '90s" paper forms the basis of our evaluation of the adequacy of the NASA aeronautical R&D program. It proposes the difficult but achievable goal of reestablishing clear-cut superiority of United States products in the world marketplace, and identifies a three-point basic strategy to accomplish that goal: target achievement by the 1990s; seek bold, innovative technology advances; and influence the competitive environment. The overall concept includes four sector strategies and a list of required new initiatives.

The "Tech '90s" report concentrates on six product areas, of which three directly relate to NASA's aeronautical programs: transport aircraft, rotorcraft and unmanned aircraft. The report's focus is on those technologies with the highest payoff or leverage; special attention was paid to those technologies with both commercial and military applications. Finally, and perhaps most importantly, the "Tech '90s" report summarizes the benefits that can be anticipated as a consequence of integrating several technologies into a single product. As detailed in the report, these potential benefits are stunning. To cite a few examples, the productivity increase for the long-range airlifter is estimated at 30 percent, along with a 50 percent increase in payload/range. For shorthaul transports, there would be a 65 percent decrease in fuel burned, and a 43 percent reduction in direct operating costs. In the case of rotorcraft, a 50 percent reduction in operating costs is estimated for conventional helicopters, and 80 percent for "hybrid rotorcraft." Keep in mind that these are achievable benefits compared to current "new" technology aircraft.

NASA's fiscal year 1985 budget for aeronautical R&T programs appears to provide significant coverage of the initiatives recommended in AIA's "Tech '90s"

report. However, our analysis suggests that neither the programs nor the proposed funding level are adequate. That inadequacy becomes more apparent from an examination of budget estimates through fiscal year 1989. While total NASA R&D increases at a respectable average annual rate of nearly 22 percent in then-year dollars between 1985 and 1989, the aeronautical R&T increases at an average annual rate of only 5.2 percent from $342.4 million in fiscal year 1985 to $419 million in fiscal year 1989. When a predictable rate of inflation is assumed, aeronautical R&T shows no real gain in buying power. Increasing aeronautical R&T at the same rate as total R&D would result in a fiscal year 1989 budget of $743 million (in then-year dollars), more than double the fiscal year 1985 budget. This increase should be accompanied by an appropriate increase in the aeronautical R&T Research and Program Management Budget.

NASA's intention to increase funding in fiscal year 1985 for the numerical aerodynamic simulator (NAS), the advanced composite structures program, the rotor system research aircraft (RSRA) and the X-wing program is highly appropriate. However, there are significant concerns as to the current and future status of NASA's propulsion programs.

After the Energy Efficient Engine (E3) programs end, there are no NASA technology programs for large turbofan propulsion systems until fiscal year 1987. This gap between large turbofan technology programs will severely reduce the availability of the advanced technology required to maintain the U.S. competitive edge in the large engine market. For commercial aviation it is estimated that the total large civil turbine engine and spare parts market will be over $100 billion (1984 dollars) over the next two decades. Continued dominance of this large market by U.S. industry is essential to our economy as well as to our balance of trade.

Long-term preliminary design studies projecting 10–20 years ahead have been initiated by NASA under the Energy Efficient Engine and Propfan programs. These studies indicate that the absence of large, advanced turbofan technology programs at NASA also impacts the advanced turboprop program. Most of the core engine technologies needed for advanced turbofan engines are also required by the gas generator for the advanced turboprop engine.

The Advanced Turboprop Program, which has industry's strong endorsement, is also inadequately funded. AIA support of increased and continuing funding of the ATP/Propfan program does not imply endorsement of either of the technological approaches now being considered. AIA's position is to continue the program with both approaches until clear-cut technical and economic superiority of one or the other can be demonstrated.

While it may not be feasible to restructure aeronautical R&T programs for fiscal year 1985, AIA urges that this Subcommittee and Congress issue a challenge to the Administration to follow through in the findings and recommendations of OSTP's 1982 report by proposing a fiscal year 1986 budget and, in fact, a five-year plan that embody the bold policy mandate of reestablishing American aeronautical product superiority in the international market. Such a program should fund generic, basic and applied research, as well as appropriate systems technology.

Subsonic aeronautics technology is far from being "mature" in the sense of having reached the point of diminishing returns for effort expended. To the contrary, the prospective advances of the 1990s far exceed the evolutionary improvements of the 1970s and 1980s. This is a point made by NASA, OSTP's 1982 report and AIA's "Tech '90s" paper.

Advanced technology for the 1990s offers the best hope for the continued strength of the U.S. subsonic aircraft industry in the decades ahead, as foreign competition has had the most significant impact in the commercial subsonic field—witness Airbus Industries A300/A310/A320 series, the new 30–45 passenger commuter turboprops, and the Dassault and Canadair business jets. The subsonic aircraft world market of the 1990s will be the largest market for aerospace products, and is expected to exceed $200 billion (in 1983 dollars). This enormous market includes all commercial transport categories from business jets and commuter aircraft to intercontinental transports, together with military intra-theater aid strategic airlifts, tankers, and command, control and communications intelligence (C^3I), and all types of helicopters.

The bottom line is straight-forward and blunt. A more strongly-focused national effort on the key technologies for the 1990s must be aggressively pursued now to ensure that the United States will maintain a position of product superiority in the worldwide aerospace market. Without this effort, the U.S. position will continue to erode.

That concludes my statement, Mr. Chairman. My colleagues and I will now be glad to address any questions.

[The following information was subsequently received for the record:]

QUESTIONS OF SENATOR GORTON AND THE ANSWERS THERETO

Question. Dr. Harr, you have made an interesting comment in your testimony that, by the year 2000, all aircraft operating today will be obsolete. If this is true, then the world aircraft market will surely experience a profound turnover in its fleet in the 1990s.

Answer. All civil aircraft operating today will be technologically obsolete by the year 2000. This does not mean that they would be retired from service, but rather that there would be no new procurement of such aircraft.

Question. Compared to our foreign competition, are NASA and the U.S. aviation industry doing what is necessary to capture the large majority of this 1990s market?

Answer. We are definitely not exploiting our opportunities for new systems based on 1990s technology. We don't know what foreign competitors are doing, but they have closed the gap in the last 10 years and could continue in the 1990s. We need a strategy and a program aimed at clear-cut product superiority. Product and production technology are our best weapons.

Question. Dr. Harr, a member of the U.S. aviation industry has recently stated that the development of advanced new aircraft is not inhibited by a lack of technological capabilities but by the cost of the development. Further, he stated that industry must turn its attention to bringing down development costs by using "imagination and vision". This statement seems to shift more of the responsibility for the future of U.S. aviation from the government to industry.

Could you comment on this individual's assessment?

Answer. The assessment is absolutely true. Our point is stronger teamwork and a stronger program is required. The argument is who bears the most responsibility for what.

Question. Dr. Harr, what advantages, if any, do experimental flight vehicles offer over the use of wind tunnels and simulations, and, more importantly, can these advantages justify the costs involved?

Answer. In general, the integration of many advanced technologies into an aircraft is industry's job. NASA experimental flight vehicles are often not appropriate or cost effective, especially in the main area of subsonic transportation. However, sometimes system technology demonstrators are essential and cost effective. For example, there will need to be demonstrations of high speed turboprops, both single- and counter-rotation, because cabin noise, community noise, and some aspects of performance and installation, etc., cannot be tested adequately by simulation or wind tunnel.

Question. Dr. Harr, looking at more advanced aeronautical concepts, could you comment on the need to develop a hypersonic commercial transport?

Answer. There is very little apparent need for hypersonic transport. We must not lose sight of the requirement for the 1990s. The need is for superior subsonic transportation, say, from 1992 into the next century. That's where 100 percent of air travel will be as well as 100 percent of the competitive threat.

Question. When might such an aircraft be needed and be economically feasible?

Answer. No one can predict.

Question. When should NASA begin serious R&D on the required technologies?

Answer. Only advanced R&D needs to be done now.

Question. What are the military implications of developing a hypersonic commercial transport?

Answer. Very few.

Question. Dr. Harr, continuing this discussion of aircraft of the future, at what point do you see the need for large commercial transport aircraft that might carry 800 to 1,000 to passengers between large population centers?

Answer. The trend is much more for flexible (hub-to-hub plus point-to-point) and frequent service. I think 800–1000 passenger aircraft are well beyond the year 2000.

QUESTIONS OF SENATOR HEFLIN AND THE ANSWERS THERETO

Question 1. At the hearing, your comments indicated that you were generally content with the President's 1985 budget request for NASA's aeronautical R&T programs. Is that correct? If not, what specific changes would you recommend to the committee?

Answer. Industry is not at all content. The Aeronautical R&D budget, including manpower and management, is only 9 percent of the NASA total. It is not in tune with the opportunity or the threat. Increase of 20 percent per year over the next 5 years in NASA Aeronautical R&D would be more appropriate.

Question 2. Your testimony focused on the need for higher levels of basic research through an increased Research and Technology base. What do you believe to be the appropriate balance between NASA's R&T base programs and the applied Systems Technology program?

Answer. AIA's focus was on systems technology in certain cases, as well as higher levels of basic research. The Systems Technology programs are very important Funding has been cut to dangerously low levels over the past few years. Some programs are necessary. Industry is best qualified to do systems integration. NASA should fund industry for more effort.

Question 3. You also discussed the need for increased funding in 1985 for the Advanced Turboprop Program. If the Committee chooses to increase funding for the ATP, especially to ensure the 1987 flight test, what areas do you think we should consider a possibilities for offsetting reductions?

Answer. AIA does not believe that rescheduling of funds within the amounts under current consideration is appropriate or cost effective.

Question 4. There is always a great deal of discussion in the aeronautics program as to how much private sector involvement there is and whether more is needed. How can NASA encourage more private sector competition in its aeronautical R&D programs?

Answer. Industry is spending a huge amount on civil R&D in aeronautics (several times the NASA budget.) NASA needs to fund more industry work in the field of 1990s aeronautical technologies and systems.

Question 5. We are told that the United States must stay on course with the Advanced Turboprop Program in order that our aircraft manufacturers will remain competitive in the 1990s and 2000s. To what extent are foreign governments and manufacturers involved in developing advanced turboprop technology and how far along are they?

Answer. They are at work, but are not yet as far along as we.

Question 6. What are U.S. manufacturers doing in preparation for the ultimate development and refinement of the advanced turboprop techology?

Answer. Many ideas have been developed, and many studies and some R&T have been conducted.

Question 7. A great deal of concern has been raised about the future of propulsion programs at NASA after the Energy Efficient Engine (E^3) program. What do you think would be an appropriate propulsion initiative for NASA after the E^3?

The NASA E^3 program had a very valuable payoff, as can be seen in G.E.'s latest CF6-80C CFM 56-¾ engines and in P&WA's 2037 and V2500 engines. NASA needs an "E^4" program aimed at the 1990s—85+ Mach Turbofans. There is no NASA program in this area beyond a few component programs. There is a big void in NASA's aeronautical planning. Turboprops will not take over everything. Turbofans are vital to the 1990s and beyond.

Mr. KREBS. Thank you, Karl. Within the AIA technical council we formed a study group of six companies—General Electric, General Dynamics, Boeing, TRW, E Systems, and Westinghouse—and we issued this report, Aerospace Technology of the 1990's.

The objective we seek is for U.S. aerospace to have clearcut product superiority in the 1990's—cost, performance, reliability, and all factors. We are convinced that very bold new technology applied to new products of the 1990's is our best bet for product and cost superiority.

Technology is really our best competitive weapon. This report concentrated on six representative product areas. It identified technologies of the greatest technological payoff, and demonstrated their applicability to these systems. We identified their individual benefits in terms of cost and performance, and, most importantly, we demonstrated, their integrated, combined benefits to these systems.

By showing the dramatic payoff of those technologies to new systems, our intent was to encourage industry leaders, and Government leaders, to adopt and support a stronger program of R&D, to concentrate more resources on R&D for the 1990's, and have a clearcut drive for product superiority.

Frankly, we are trying to build some new vitality into longer range planning and longer range R&D. We want to show decisionmakers what is really possible by applying this advanced technology. We are trying to provide a new and more coherent vision of the 1990's, show some new options, identify some new capabilities, and hopefully gain some additional support.

I think of special interest here today in this forum on NASA aeronautics are the technological prospects for some of the aeronautics systems that we looked at, which included long-range transports, short-haul transports—these could be both military and commercial—and rotorcraft. We think our findings and conclusions are generally applicable to commuter aircraft, business jets, and general aviation.

The integrated benefits from these technologies is truly, truly dramatic. We find, for example, that you can have from 30 to 50 percent better operating costs than we have today in a wide spectrum of aircraft. Just to take, for example, a short-haul transport, 65 percent less fuel burned, 43 percent lower direct operating cost. That is $3 million per year per aircraft savings in operating cost.

In a long-range airlifter, something you could have in the latter part of the 1990's, commercial or military; 30 percent improvement in productivity, 50 percent improvement in range payload, 30 percent reduction in life cycle cost, which over a fleet of 100 aircraft in 20 years would be $9 billion savings. These are gigantic savings, the benefits that come from the applications of advanced aerodynamics, structures and materials, avionics, propulsion, flight controls, and advanced subsystems.

We have got to reach out beyond the sort of evolutionary design that is the current focus of much of the industry and Government. We have got to leapfrog into the next decade and get these large benefits.

When we examined the adequacy of the NASA aeronautical budget we see that it covers the kinds of technologies that we are talking about here. And there are some very good programs, and we are pleased, as you were, Mr. Album, that there is an increase over fiscal year 1984 in this budget. But the fact remains that neither the programs nor the proposed funding levels are adequate to in anyway assure product and cost superiority for the 1990's.

The scope of these programs and funding are just not in line with the opportunities that I named, and they are not in line with the competitive threat, as we see it. This is especially true in the subsonic, fixed-wing aeronautical area because this is the area where the commercial market stakes are the highest, foreign competition is the toughest, the DOD sponsorship of technology is the least. It is a very, very tough, tough area.

Although the budget is up 13 percent, it is up from a relatively low point. The R&T budget of aeronautics is $342 million. Back in 1973 in constant year dollars, it was greater; it was $400 million then. And it has been higher in periods in between. So there has

been a rather steady erosion to this effort which we are now just beginning to get back, and even this increased aeronautical R&D figure represents, with its people and program management added to it, around 9 percent, only 9 percent of the NASA budget.

If you look out into the future, there is really a continuing problem here because the NASA budget in R&D, which increases at a rate of nearly 22 percent a year only provides aeronautical increases of 5 percent per year. After inflation, we will be seeing practically no real increase in the aeronautical budget.

We think really what is needed is something like a 20 percent per year increase. Over the next 5 years we really ought to double the amount of aeronautical R&D, double it in order to get these very large benefits across a very wide spectrum of important systems. We need this because the foreign competition has a huge impact in the subsonic field: For example, the Airbus Industries' efforts on the A-300 and A-310, A-320 series, the 5 or 6 new foreign commuter transports, in the 30- to 60-passenger area, the Dassault and Canadair business jets, the Areospatiale helicopters. Note that the subsonic aircraft market, commercial and military, in the 1990's is probably a $200 billion market. We ought to have, I think, a much more vigorous aeronautical program aimed at achieving clearcut product superiority.

This program would fund generic basic and applied research and certain appropriate systems technology. But certainly we need, if our objective is to have leadership and superiority in the United States, a more vigorous program than what we have now.

That concludes my statement, sir.

Senator GORTON. Thank you.

Mr. Album, in Jim Beggs' testimony before this subcommittee last month the NASA Administrator said that the reason CMB reduced the funding for the advanced turboprop for fiscal year 1985 was, and I quote:

> That it was too early to tell whether the industry might pick this up or not, and that it was not judged to be an imperative or particularly pressing investment to move on to the flight test program.

Could you comment on this rationale and the urgency with proceeding with the flight test program by 1987? And can you tell me whether industry should assume more responsibility for the development of that technology and what the impact of the $14 million authorized would be?

Mr. ALBUM. Senator, I do not know how to comment in regard—I do not know the exact context in which the statement was made that it was too early to tell whether the industry would pick it up or not. My group, I know, feels that that is the very purpose of the prop fan program. If the risk was low enough that we knew the industry would pick it up, the industry would pick it up and we would not need a NASA program.

I have identified in the written testimony five major technological gates through which the prop fan program must pass in order for there to be enough momentum and certainty that industry would pick it up. One of the major costs is developing an engine for the prop fan, which industry is going to have to do. Industry will have to develop a new aircraft for the prop fan or develop a prop

fan derivative of an existing aircraft. There are enormous expenses involved there. By comparison, the cost of the NASA prop fan program to get it through these technological gates is relatively small.

Let us talk for a moment about the urgency. The foreign competition is going ahead with the A-320 aircraft. The A-320 will compete with a number of our existing aircraft. They will compete with the Douglas MD-80. On different sides of the scale it will compete with the 737 and 757, particularly in the form of A-320 derivatives. The A-320 will compete with these aircraft as a whole new aircraft.

The advanced turboprop, prop fan in particular, and possibly a counter-rotating advanced turboprop as a follow-on possibility, or competing concept, will give the prospect of an entire leap over the A-320. The prospects are for a reduction in fuel consumption in the order of 20 to 30 percent, depending upon which of those two concepts you wind up using.

The effects on the competition would be almost disastrous because of this leap. It is possible to field this aircraft in commercial sales, technically possible and programmatically possible, by 1993 if the program, if the flight test program, the currently planned flight test program, for the 9-foot LAP/PTA propeller are conducted on schedule.

If they are not conducted on schedule, if the funds are not there to conduct those tests and also to fund the small-scale tests for the competing concept of the counter-rotating system, then we are going too little and too late on this thing is what it amounts to. We will not be in in time to compete.

We have a lead now on the prop fan. Are we going to press this forward, or are we going to continue to stretch it out? That is the question. If you stretch it out you have to pay the money at one time or another and you just may wind up coming in too late, sir.

Senator GORTON. Should we be going to both the single rotation technology and the counter-rotation technology at the same time or concentrate on one or the other?

Mr. KREBS. Senator, let me talk about this from the industry standpoint. There is more than one very promising system in the high-speed propeller. The prop fan is one of these. There can also be counter-rotating gear drives and counter-rotating gearless drives. Some of these latter ones are a bit newer on the scene.

NASA has to have a program, I think, to systematically sort out the merits, problems and opportunities in these systems. It is probable that more than one combination will be preeminent in various fields. In the very small size, one may be best; in the very large size, one may be best. In the speed range of 0.7 one may be best, or in the speed range of 0.8. All that has got to be sorted out.

I think before one proceeds to spend very large moneys in flight test there is quite a bit more basic work that has got to be done on both.

Mr. ALBUM. I have a somewhat different point of view from my group in regard to the merits of how to proceed on a program including counter-rotating and the single rotating prop fans. The counter-rotating prop fan offers the prospect of, on conceptual studies, of an improvement in the order of 30 to 31 percent fuel effi-

ciency. The single rotating offers the prospect of roughly about 22-percent improved fuel efficiency.

So if you look at these conceptually the natural tendency is to say well, let us go with the one that conceptually looks the best. But in technology is it often the case that when you are in the process of pursuing a program vigorously a more appealing concept comes on the scene.

Our group feels that the flight test program on the 9-foot diameter prop fan should be pressed forward. This prop fan technology development program has been underway since 1975. It has passed all the prerequisite gates of studies, small-scale ground testing and small-scale flight testing. We should press this technology forward. The planned flight test program for the 9-foot prop fan will produce technological information of value to the counter-rotating concept as it goes through its phased small-scale tests and then possibly into large-scale tests later on.

If these funds and efforts are divided and progress is delayed on the basic prop fan you will not get either one in a reasonable period of time. This does not seem to be a proper way to phase the program, sir.

Senator GORTON. Dr. Harr, according to your testimony, after the completion of the energy efficient engine programs there are no NASA technology programs for large turbofan propulsion systems until 1987. You have also said that this gap between large turbofan technology programs will severely reduce the availability of the advanced technology required to maintain our competitive edge in the large engine market.

Can you be more specific about the impact of this gap, perhaps who you think might fill it, and tell me whether or not this indicates that NASA erred in its scheduling and prioritization of these programs?

Mr. HARR. Well, I think our statement implies that they erred at least in some degree in doing that, Mr. Chairman. I am shy of being too expert on this because there is a greater expert sitting on my right here who probably could answer that better.

Mr. KREBS. Well, the E-3 program was a very successful NASA program and generated a lot of very major advances in propulsion, many of which are now being applied in the next generation of turbofans. I think NASA would like to have had a follow-on to that E-3 program, and should have one and would have had one if the budgets could have been larger.

Instead, with the budgets available they have to limit themselves mainly to sort of component tests. There is some fan work that is being done. There is some compressor work that is being done, relatively small in scope work. I think it would be very important at some point that we have an E-4 program to push ahead into the turbofan technology of the mid-1990's.

Senator GORTON. Does it look like the Europeans or the Japanese or someone else will have such a program?

Mr. KREBS. Somebody will. The technology is being pushed right along. There are a lot of ideas out there and a lot of materials and processes, plus new advancement in aerodynamics by way of 3D computational aerodynamic work.

Let us not get the idea that all propulsion of the 1990's is going to be turboprop or any form of turboprop. I think we are going to see most long-range systems still powered by turbofans. We really need some sort of an E–4 program.

Senator GORTON. With the Airbus decision to develop the A–320, is Airbus likely to increase its present share of the world market and, if so, what is the likely impact?

Mr. HARR. Well, the managements of all our remaining airframe companies and engine companies are scratching their heads on that impact question daily—and because of the interwoven elements of competition for the market for the 150-passenger transport, you know, they probably cannot even predict with accuracy the answer to your question.

But you could say a couple of things. One, any share they will get will be a share taken away from us. Two, they will get some share, some substantial share. Three, they do not seem to have it yet. They seem to have orders, fixed orders, falling far short of their announced break-even point. Four, they will have the support of the British, French, and German Governments in a way that we will never get from our Government and probably should not.

I am not saying we should try to emulate some of the things they do, but it will be a hard-fought battle and a life-or-death struggle for them, to some extent. Allan Boyd is convinced that there is room for both of us and that they are going to get a share that will not necessarily commensurately reduce the proportion or volume of our sales over the next 15 to 20 years.

I find that hard to believe. Of course, there is an expanding market that most manufacturers predict. Yes, it is a dogfight. It is a dogfight. It brings into consideration all of the elements of Government policy and economic policy on both sides of the Atlantic.

I would say one more thing: The business of selling commercial transport aircraft, civil transport aircraft, is a global business in terms of the resources necessary to underwrite the risk of developing new aircraft, and the market share or the market area that you must be able to sell in.

We are going to see continued suggestions that U.S. antitrust laws be modified to allow a combination of efforts by two American companies, and we are going to see more joint ventures between American companies and foreign companies all over the world. And there is no question that getting market access to certain countries will continue to necessitate offsets on coproduction arrangements of some kind. The point again, is that there is no way you can build a modern civil transport aircraft on the basis of the domestic U.S. market or any other single country's market.

Senator GORTON. Mr. Album.

Mr. ALBUM. I would like to comment on the technical significance of the A–320, if I might. The A–320 is a very curious decision on the part of the Airbus Industries. The reason it is a curious decision is that it comes into such competition with a number of existing U.S. aircraft. Usually companies try to, you know, find a special notch and jump right into that notch.

The A–320 would compete very directly with the MD–80, and its performance is not that much better, but it is an all-new airplane and it is a European airplane. That could very seriously hurt, in

my opinion, my personal opinion, the market of that aircraft, particularly in Europe.

It would compete with a somewhat stretched 737 and it would also compete at another end with a somewhat reduced 757. I think, as you know, Boeing has signed an understanding with the Japanese that if Boeing goes ahead with a 150-seater that—this has been in the press; I have not talked to Boeing about it—that they would do it jointly, but they have not made that decision possibly because of the uncertainties of that market.

But I think the important thing here in terms of the propfan is you could possibly retrofit a propfan on, for example, the Douglas MD-80 or possibly a Boeing aircraft, and it would leapfrog right over the A-320 in almost the same time period, if the propfan program is pressed forward.

Senator GORTON. Thank you.

Gentlemen, I have a number of additional questions for you, but no more time. We will submit them to you in writing, if we may. We have about a month before we go to markup on this bill, and we would appreciate your answers as promptly as we can receive them, as we have appreciated your contribution to this hearing today.

Mr. HARR. Thank you, Mr. Chairman.

Mr. ALBUM. Thank you, sir.

[Whereupon, at 11:50 o'clock a.m., the subcommittee adjourned, to reconvene upon the call of the Chair.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

U.S. SENATE,
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C., March 29, 1984.

Hon. HOWELL HEFLIN,
Ranking Minority Member, Subcommittee on Science, Technology, and Space, U.S. Senate, Washington, D.C.

DEAR HOWELL: I would like to lend my strong support to the Prop-Fan program in the NASA Aeronautics budget. In order to achieve commercial application of this fuel-saving concept in the 1990's, it is critical to hold a proof-of-concept flight test of a large Prop-Fan in 1987, at the latest.

The Administration's fiscal year 1985 request includes $14M for this program NASA has testified that approximately $41M is needed in fiscal year 1985 if this program is to remain on schedule. NASA has also indicated to the House Science and Technology Committee that $24M in fiscal year 1985 would be adequate to protect the 1987 flight test, but that such a funding level would require supporting technology efforts to be stretched out.

I ask you and your Subcommittee colleagues to raise the finding of this important program in the NASA budget to ensure that the Prop-Fan will become a major element of aircraft propulsion technology for future decades.

Sincerely,

CHRISTOPHER J. DODD,
U.S. Senator

STATEMENT OF JAMES I. MUELLER, PROFESSOR OF CERAMIC ENGINEERING, UNIVERSITY OF WASHINGTON

Over the past eighteen months, a series of meetings have been held, attended by 21 individuals from 12 U.S. companies involved in the application of ceramic materials in heat engines. The purpose of these discussions was to summarize their concerns and recommendations regarding the need and implementation of a major development initiative for such a program and to so inform the appropriate branches and agencies of government. On behalf of these individuals, I wish to express appreciation for the opportunity to share these views with your committee.

I believe an introductory review will be helpful as a means of gaining an insight into the importance of an appropriate research and development program in this area. In so doing, certain excerpts will be taken from an overview paper I presented at a National Science Foundation Workshop last June.

Much of the advanced technology affecting the U.S. economy and national defense is materials limited. New systems and/or substantial improvements in the capabilities and efficiency of existing systems could be achieved if new or improved materials were available. This is particularly true of the potential utilization for advanced ceramic materials in transportation and energy applications, such as uncooled diesel and gas turbine engines, production of synthetic fuels, cogeneration, waste-heat recovery and solar concentrator electrical generation. The substitution of ceramic materials for metals in heat-engines has been given substantial world-wide attention in recent years. It should be noted that the prime purpose for considering these replacements in the early 1970's was to utilize the higher temperature capability of ceramics to improve automotive and truck emissions. With the development of the oil crisis in the mid-70's, the potential for fuel economy was also recognized and it is now apparent that ceramics can also replace vulnerable metals in this particular application.

By their very nature, ceramic materials are brittle. This does not mean they are weak but rather they have little forgiveness, or strain capability. They therefore fail

catastrophically rather than with the relatively slow deformation exhibited by most metals. Due to this and lower tensile strength, they are susceptible to the presence of flaws which in the present state of our processing technology occur all too often. The designer therefore questions the reliability of ceramic materials and we are low on the learning curve in the solutions to this problem.

In this country, the first major federal-funded program was the Ford-Westinghouse study initiated by DARPA in 1971. Although the principal thrust of this project was to improve methodologies for designing with brittle materials, the ceramic gas turbine engine was used as a model. The early success of this program and the developing fuel crisis led to additional support, as shown in Figure 1 after Lenoe [1]. This involved the expenditure of approximately $115 million, not including corporate fundings, during the fiscal year period 1974–81 and resulted in significant progress. In their final report on the DARPA program, Ford reported [2]:

"With respect to the question: 'Can ceramics work? The DARPA/Ford program has shown that 'Yes, it can be done.' The real question on which we must now focus is. 'Can it be done consistently and reliably so that it won't fail.' . . . In ceramics, because of their extremely probabilistic behavior, the 'it won't fail' phase really has to be accomplished through a research effort. The dilemma is, however, that production development-type funding is not normally applied to address a research issue. As a result, a step-by-step approach should probably be taken." This last statement definitely addresses where we are today. The feasibility of the concept has been proven but the research necessary to improve beginning materials and their processing leaves considerable to be accomplished.

The British were the first to become involved in ceramics for heat engines, following by a substantially larger effort in this country. West Germany entered the picture in 1974 with Japan following in 1977. One of the prime differences between our programs and those across each of our bordering oceans is that both the Japanese and West Germans have placed a larger percentage of government monies in support of the materials suppliers and processors.[3] This has caused some observers to feel that the U.S. is no longer in the dominant position world-wide.[4] (Figure 2).

Only a small fraction of U.S. research support for heat engine development has been allocated to the ceramic materials suppliers. This and the lack of funding to improve processing (manufacturing) of ceramic components could be the principle reason why the U.S. position is weakening in this area. If we are to be competitive, this segment of our industry needs immediate attention.

We are at a point of decision, one which will require a major cooperative effort between government and industry since it will involve substantial outlays of money by both if U.S. industry is to be competitive in this market area. Johnson et al. recently published an economic analysis of the structural ceramics research program in which they predicted the potential U.S. penetration for ceramic components in heat engines, as shown in Table I.[4] The use of ceramics as a structural material in high technology application involves reliability factors never previously considered for this type of material and is also dependent upon relatively new materials. Since such an effort effectively "started from scratch," the research to understand the materials properties and the development or processing methods necessary to produce a suitable engineering product requires funding beyond the abilities of any single company or even a consortium. There are numerous defense applications of these materials but their future will be in the civilian sector.

Obviously, the high potential exists, but what about the high risk? During the past several years, several meetings took place during which representatives from U.S. engine manufacturers and producers of ceramic materials discussed various aspects of this problem. All agreed that the cost of materials and process development would be prohibitive without long term government assistance. If we now review the National Materials & Mineral Progress Plan and Report to Congress, we note President Reagan stated: "Any government-financed research and development action activities will concentrate on long-term, high risk, high potential payoff projects with the best chance for wide generic applications to materials problems

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[1] E. M. Lenoe: "Overview of DOD Ceramic Heat Engine Technology Projects," *Proceedings of DOE/EMACC Meeting*, CONF–820911, Department of Energy.

[2] A. F. McLean and E. A. Fisher, "Brittle Materials Design, High Temperature Gas Turbines." Final Report. AMMRC TR 81–14, Ford Motor Co., March 1981.

[3] J. I. Mueller: "Handicapping the World's Derby for Advanced Ceramics," *American Ceramic Society Bulletin*, Vol. 61, No. 5, 1982.

[4] L. R. Johnson, A. P. S. Teotia and L. G. Hill, "A Structural Ceramics Research Program and Preliminary Economic Analysis," A Structural Ceramics Research Program: A Preliminary Economic Analysis," Argonne National Laboratory, Dec. 1982.

and increased productivity." Certainly this application of ceramics in heat engines meets these qualifications.

During these meetings, it was noted that while foreign companies are investing heavily in advanced ceramic structural materials, their governments permit tax write-offs and depreciation not permitted in this country making it difficult for U.S. industry to compete. This relates to another of the President's materials policy statements, that * * * "favorable tax incentives in the Economic Recovery and Tax Act (should) stimulate private research and development to ensure the availability of materials essential to the nation's economy and national defense." The question here, and one which I cannot answer is—do today's tax incentives offer sufficient stimulation to already depressed industries?

Another factor that must be considered by those whose funding is being utilized in the development of high technology ceramics is time—the bridge from concept to commercialization. Today few would look upon the automotive spark plug as being high technology. Yet 40 years ago ceramists world-wide, particularly in Germany, were in the midst of basic research involving the sintering of aluminum oxide. In the immediate post-WW II period, the U.S. automotive industry, recognizing the need for a spark plug with higher temperature capabilities with high voltage insulation properties, turned to sintered aluminum oxide as the appropriate solution. It took almost 25 years to get from research to commercial production.[5] Based upon this time frame and using 1971 as a starting point, the earliest utilization of ceramics in a gas turbine could be in the mid 1990's, a period which matches the estimates of engine manufacturers in West Germany, Japan, and Sweden.

If we are indeed in the research phase in the development of ceramics for heat engine applications, can we compare our present systems with another, more mature area involving high technology ceramics? The utilization of ceramics in the electronics industry may be an appropriate example. Professor Bowen of MIT generously offered information on the 1981 value in U.S. sales of certain ceramic components to the electronics industry which are given in Table II.[6]

The solutions to today's problems for heat engine ceramics are substantially greater than those which the electronics ceramic industry faced 15 years ago. It is safe to assume that the U.S. holds about at least a 40% share of the world's market for electronic ceramics which according to Bowen's figures, is about $1.3 billion. If the U.S. were to obtain 40 percent of the world's market for ceramic engine components, an extrapolation of Johnson's estimate would be $6.1 billion per year by the year 2000.

CONCERNS

The considerable discussion involved concerns about U.S. materials R & D policy and about preliminary plans for a heat engine ceramics program initiative as presented by the National Aeronautics and Space Administration's Lewis Research Center and the Department of Energy's Oak Ridge National Laboratory. The following statements summarize these concerns:

The availability of reproducible, quality starting powders for fabrication of advanced structural ceramics is inadequate.

Current ceramic materials are highly variable and result in inadequate reliability, resulting in an excessive risk for current engine development programs.

A high priority effort of iterative processing and equipment development is required to achieve mature process control, improved materials properties and net-shape fabrication capability.

Foreign competition in this area threatens the viability of U.S. industry.

The stated U.S. National Materials Policy should include the capability to focus on critical materials cases. Although substantial government funding has already been dedicated to materials R & D, there has not been appropriate recognition by its agencies on proper focus or objectives. Specifically, in the case of the heat engine program, the planning resulted in efforts guided into commercialization programs rather than allocating resources towards a ceramic technology program. Only by the establishment of appropriate goals with their attendant objectives, implemented by a sustaining research and development effort, can our country focus on a national development effort.

It is imperative for government laboratories to support industrial R & D programs through cooperative efforts to identify and achieve program objectives. If technology

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[5] M. Berg, "The Sparkplug: A Case History," presented at the 6th Army Materials Technology Conference, Orcas Island, WA, July 1979.

[6] H. K. Bowen, Personal communication.

is to produce new jobs and improve our economy, it must be based in industry, with coordinated efforts involving government laboratories and universities, utilizing the special expertise of all concerned.

Government contracting methods need thorough reassessment relative to tax incentives and proprietory information practices as these are crucial to maintaining a competitive U.S. posture in the international marketplace. It is sorely apparent that other countries are making an overwhelming effort to bring advanced technology products into the world's market without the penalties currently imposed upon U.S. industry by unfavorable tax regulations and the requirements of unreasonable revelation of key innovative competitive factors relative to product development and production.

TECHNOLOGY BENEFITS AND PROGRAM REQUIREMENTS

The first question considered by the group was whether or not potential benefits of the use of advanced ceramics materials in heat engine technology would justify a major R & D effort. The following is a list of advantages or benefits: Greater fuel economy; Utilization of low quality fuels; Compatibility with synthetic fuels; Reduction in strategic materials; Potential cost reduction; Reduced maintenance; Applicable to both commercial and military requirements; Deletion of cooling systems; Resistance to corrosion and erosion; Improved emissions control; Wider range of properties; Would lead to new industries; and Would increase the U.S. GNP.

It was the concensus that a major program was required if the U.S. is going to meet international competition.

The goals and organization of such a proposed program were considered and, as stated, most agreed that the major constraints were high risk, high cost and the lack of reliability in present materials since primary funding in the past was directed towards the proof of concept programs with engine manufacturers which have demonstrated feasibility.

A proposed solution was to substantially increase the level of effort for ceramic materials producers and fabricators. The following were topics where significant improvements should be sought by a future program. These are in total agreement with the recommendations of the National Materials Advisory Board Committee on Reliability of Ceramics for Heat Engines.[7]

Beginning Powders; Strength; Reliability; Cost Effectiveness; Processing Methods; Nondestructive Evaluation; and Finishing.

It was the majority belief that power development and component processing, including finishing, were the keys to the required reliability and that advanced NDE techniques are necessary. This is compatible with the objectives identified by NASA/LRC and DOE/ORNL for their ceramic initiatives. If was further agreed that the ceramic materials producers and fabricators should be encouraged to participate as possible recipients of new funding, but that judgments for selection be based upon choosing the company(s) best qualified in terms of expertise, facilities and ideas to undertake the jobs. There must be close liaison with continuing heat engine programs as the achievement of reliability will require iteration between material development and engine testing of components.

The most effective utilization of government and university laboratories also received considerable attention. All recognized the existing expertise and agreed that its use would be paramount to the success of the program. Numerous topics were suggested as being suited for study by those groups, including: generic basic research on materials; characterization methods; deveopment of NDE; corrosion and erosion research; and advanced processing methods.

The consensus opinoin was that both be supported on primarily basic research but that certain government and university laboratories be recognized as having unique expertise in specific areas and that these be encouraged to further develop those capabilities. This, for example, would result in laboratories with unique facilities for testing and evaluation, characterization, finishing and NDE. These would be available to industry on a contract basis, reducing the need of capital expenditures for redundant capabilities. It was further stated that encouragement should be given universities to initiate and accomplish appropriate basic research which could result in improved structural ceramics and a more complete future understanding of their inherent and potential properties. Although research on advanced processing was deemed appropriate for university efforts, several suggested that improvements in current processing techniques would be more efficiently studied within industry.

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[7] "Reliability of Ceramics for Heat Engine Applications," Report Number NMAB-357, National Materials Advisory Board, National Academy of Sciences, Washington, D.C., 1980.

To assure success of such a program, organizational improvements should be made in order that all activities are implemented in a coordinated and effective manner while maintaining the individuality of each activity. This coordination should assure that the research, development and application sectors maintain mutually effective and cooperative relations in order that use of the results will be maximized. It was felt, therefore, that the responsibility for coordination of the programs should be assigned within a single government activity, acting with a strong industrial advisory group.

It was also noted that foreign companies are investing heavily in advanced ceramic structual materials, and their governments are permitting tax write-offs and depreciation not allowed in this country. This makes it difficult for U.S. industry to compete and relates to another of the President's materials policy statements, that . . . "favorable tax incentives in the Economic Recovery and Tax Act (should) stimulate private research and development to ensure the availability of materials essential to the nation's economy and national defense."

CONCLUSIONS

(1) Cost, risk and reliability are the major constraints to the application of high technology ceramics to heat engines.

(2) Foreign competition may be overtaking U.S. technology in this area due in a large extent to government-industry cooperation and commitments.

(3) A national rsearch and development program, with emphasis on research, should be established to improve domestic production of consistent, high quality ceramic powders and the concomitant processing with the ultimate goal being to develop structural ceramics technology for industrial and defense utilitization.

(4) The R&D required would be generic in nature, having applicability in high technology areas other than heat engines.

(5) R&D programs should be funded to the ceramic industry and other industrial organizations with the capability and interest to contribute, and with continuing support to the heat engine programs as test-beds for the assessment of improved ceramic materials and components.

(6) For such a program to be effective, it should be supported by sustained government funding supplemented by long-term corporate commitments.

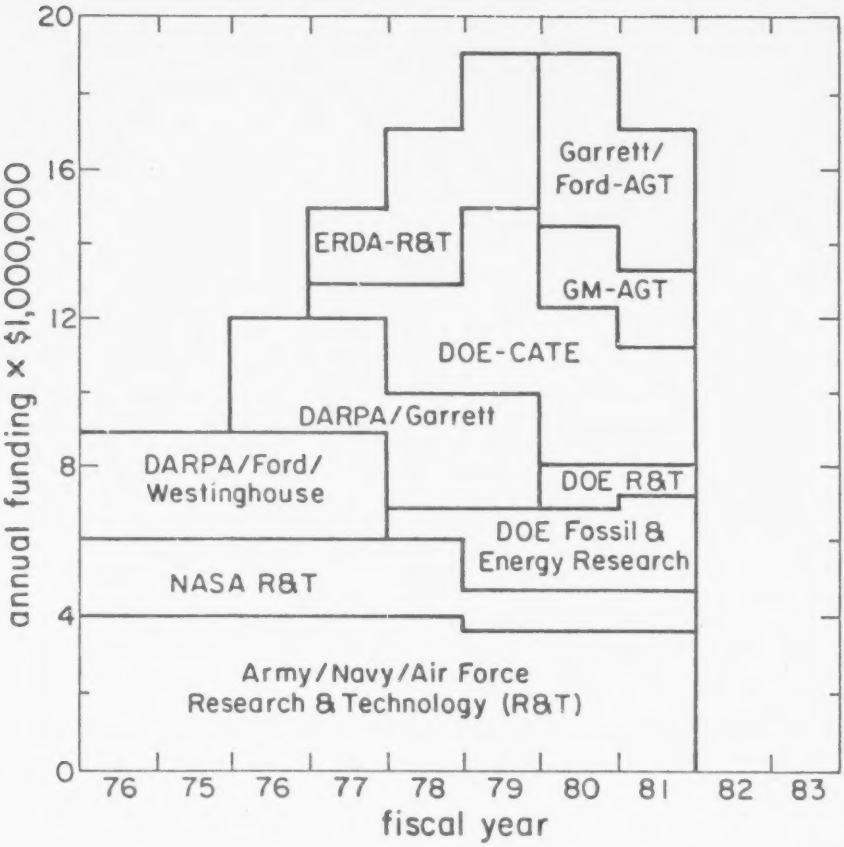
(7) University and government laboratories should be encouraged to develop and establish unique characterization capabilities which would be available to other laboratories and to industry for environmental testing and data-base generation which can be used for design and design verfication.

(8) Initiation of this program at an increased level of funding is esential if U.S. industry is to remain competitive in the international marketplace.

(9) A program should be immediately developed and implemented to offer encouragement of industrial participation through tax incentives and through the relaxation of existing bureaucratic requirements relative to multiple and short-term reporting and to the international revelation of innovative and competitive methods and products.

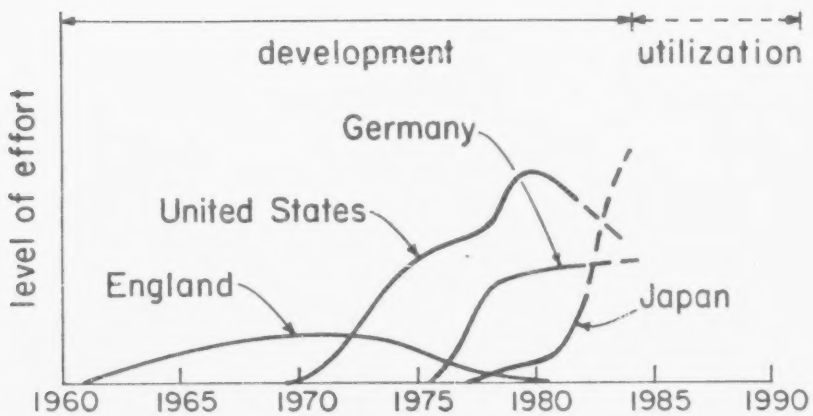
(10) This national program must be coordinated, preferably by a single government office, with assistance from an industry advisory group to assure focused efforts, proper communication and coordination and continued, long-term planning.

(11) This group will continue to meet periodically, with interim informal communication, with the intent to formalize its organization, to keep all informed of national and international developments and to advise our government relative to matters of interest and concern.



U.S. Funding of Ceramic Gas Turbine Engine Development
YRS 1974-1981

Figure 2



A Generalized Comparison of Structural Ceramics Activity

Figure 1

Table I.— A Range of Market Penetration for Ceramic Components

[For year 2000]

	(1981$ x 10^6)	Percent market penetration		Market penetration (1981$ x 10^6)	
		Low	High	Low	High
Diesel/gas turbine components:					
Piston, piston rings, valves[1]	$1,807	0.05	0.20	$90	$361
Cylinder liners, head insert[1]	1,984	0.05	0.20	99	397
Bearings	6,379	0.05	0.30	319	1,913
Turbochargers	306	0.05	0.75	15	230
Gas turbines, except aircraft	449	0.05	0.30	22	135
Total	10,925			545	3,036

[1] Inciudes gasoline and diesel engine parts for all applications.

TABLE II.—U.S. Sales of Electronic Ceramics, 1981

Item:	*Millions*
Capacitors	$400
Substrates/packaging	500
Magnets	150
Magnetic tapes	150
Thermistors	60
Varistors	30
Total (billion)	1.290

STATEMENT OF TASK FORCE ON CIVILIAN SPACE POLICY, AEROSPACE DIVISION, AMERICAN SOCIETY OF MECHANICAL ENGINEERS

INTRODUCTION

The American Society of Mechanical Engineers (ASME) is an educational, scientific and charitable society founded over 100 years ago. Membership in ASME exceeds 100,000 mechanical engineers. Because of the variety of applications of mechanical engineering, about 20 percent of our membership is directly involved in the aerospace industry. Many more are involved as second and third tier contractors.

This statement was prepared by the Task Force on Civilian Space Policy of the ASME Aerospace Division, and represents the considered judgment of the Task Force, a group of experts in the field, rather than an official position of ASME.

Traditionally we prefer to comment on technical issues, and we will confine most of our comments to selected programmatic aspects of the proposed fiscal year 1985 budget of the National Aeronautics and Space Administration (NASA). However, we are also vitally concerned with engineering man-power issues as they affect the aerospace industry and NASA's ability to meet its goal.

In general, we are pleased to see the funding increases in the proposed NASA budget; and we are enthusiastic about President Reagan's directive to NASA to develop a permanently manned Space Station. Also, we believe the ability of NASA to hire almost 600 recent science and engineering graduates in 1983 is a good sign that NASA recognizes the importance of getting new, young technical personnel into the agency.

SPACE STATION

The Task Force enthusiastically endorses the permanently manned space station program. We believe this program will enable the U.S. to maintain its technological lead in the peaceful uses of sapce. The benefits to mankind from just a few applications, such as the development and manufacture of metallurgical alloys, pharmaceuticals and semiconductor crystals, could include the control and/or eradication of diseases; the continuation of the miniaturization and cost reduction of computers; and the development of lighter, stronger and more cost effective alloys which will for example, lead to lighter and more energy efficient vehicles and machinery.

As part of the design, development and fabrication of the space station, we also anticipate a quantum leap in the development of strong, light, efficient structures

which could lead to the development and/or expansion of related earth bound industries.

We strongly recommend that the Administration, Congress and NASA very carefully plan the scheduling and funding of the space station program to insure its timely completion without the costly pitfalls caused by program stretchouts, stop and go financing, and general fund starvation.

The financial benefits of the program can be expected to easily exceed program cost. These benefits not only divert income to aerospace industry employees for the design, development and operation of the space station, but will also result in income to the employees of the new industries created by the space station. In addition, indirect monies will filter through to those members of the communities servicing the direct income people. And, of course, it will have a positive impact on the national balance of trade.

UPPER STAGE DEVELOPMENT

Over the past decade, NASA and the Air Force have been or are developing upper stages to deploy shuttle payloads from low earth orbit to geoslynchronous orbits. These upper stages include the Inertial Upper Stage (IUS) with a 5000 pound capability, a reconfigured Centaur with a projected 10,000 pound capabiltiy and the Propulsion Assistance Modules (PAM). The track record for launches from the space shuttle with some of these upper stages has not been very encouraging to date. we firmly believe that funds should be provided to resolve technical problems with existing upper stages as well as initiating a reassessment of upper stage needs to determine if the current mix of upper stages is adequate to support the needs of NASA 's civilian and DoD customers.

We believe that a more versatile upper stage vehicle will be required to operate from the space shuttle and from the planned space station. This vehicle may even be manned, and it should have the capability to ferry satellites, etc. from low earth orbit to geosynchronous orbit and back with stops in-between. This vehicle should also be capable of retrieving inoperative (inactive) satellites.

Therefore, we recommend that NASA include an advance satellite ferrying and retrieval system as a specific program objective to support the space shuttle and space station programs.

FIFTH ORBITER

Prior to the recent announcement of the space station program, we felt that the current space shuttle flight schedule for the four orbiters was very "success oriented." Last year we recommended that NASA be authorized and funded to purchase a fifth orbiter. We also recommended that private industry be encouraged to purchase this vehicle if NASA could not. With the start of the space station program, several orbiters will probably be required to ferry parts into space for the space station. will four orbiters be able to accomplish the space station ferrying requirements in addition to the projected satellite deployment? We doubt it. NASA will either need to purchase additional orbiters now or design, develop and produce a follow-up to the shuttle, say Shuttle II. The latter course of action might well turn out to be the most cost effective approach.

UNMANNED PLANETARY SPACECRAFT

The Task Force heartily supports the recent recommendation of the Solar System Exploration Committee (SSEC). This NASA advisory committee recommended an economically feasible approach to the unmanned spacecraft program. This consisted of two families of spaceraft: a planetary observer class for exploration of terrrestrial planets (ie, moon, Mercury, Venus, Earth, Mars) and a Mariner MK II class for missions beyond the inner solar system including comet rendezvous and asteroid fly-by missions.

We were happy to learn of the approval of the Venus Radar Mapper in the fiscal year 1984 budget. This represents the first budget of approval of an unmanned spacecraft since Galileo was approved almost 10 years ago. we were very pleased to hear President Reagan recommend the pursuit of the Mars Geoscience/Climatology Orbiter in his 1984 state-of-the-union address. These programs represent a first step toward the low cost recommendations of the SSEC in the planetary observer class. We hope that one of the Mariner class spacecraft will also be funded in the near future. This would provide a viable approach for the U.S. to regain its pre-eminence in exploration of our solar system.

During the last few years the nation's position and our image in the planetary exploration area has deteriorated. We have failed to honor our commitments to other world bodies. For example, currently three consortiums are going to intercept Halley's Comet involving the USSR, Japan and the European space Agency with the absence of the United States.

Further, the European Space Agency is developing a probe for the Solar Polar Mission which the U.S. was committed to support. As with the Halley's Coment Mission, both were terminated due to lack of funding. The consequence of these actions is to reduce the pioneering spirit within this country which has been a major driving force behind U.S. accomplishments in the world. We see a viable recovery with the funding and implementation of the Venus Radar Mapper and the Climatology Explorer Scientific Mission to study the geology and meteorology of the planet Mars. This mission will provide the basis for better understanding of weather patterns and earth geology by comparative planetology.

MANPOWER

NASA Administrator James Beggs told a House Subcommittee earlier this year that the agency was able to hire almost 600 recent science and engineering graduates in 1983. This was a very welcome improvement in the aerospace industry manpower situation.

Since the late 1960s, the aerospace industry has experienced a number of major manpower retrenchments which have resulted in several manpower age gaps in the engineering and science industry work force. Not only were the laid-off engineers and scientists lost to the industry, but their children, seeing the impact unemployment had on their parents, may be more hesitant themselves to enter into a career in engineering and science.

The aerospace industry has a very poor reputation for employment stability. Many of us have wondered: "Who will replace us?" Aerospace engineers are generally over 50 years of age, and we have a few colleagues in their 40's, and 30's; but will there be enough when the engineering classes of the late 1940s and 50s retire?

In summary, NASA's manpower initiatives are reversing the negative age trend in the aerospace industry, and we hope it continues.

SUMMARY AND RECOMMENDATIONS

Summary

The Task Force supports the increase n the NSAS budget, and we are especially pleased with the directive for NASA to start the space station program. We are also pleased that NASA is finally able to bring newly graduated engineers and scientists into the agency.

Recommendations

We recommend that:

(1) Planning and financing of the space station be authorized and appropriated adequately by Congress to assure the attainment of reasonable goals within reasonable time and costs;

(2) Satellite ferrying and retrieval spacecraft be developed to complement and/or replace the current mix of upper stage craft in support of future space shuttle and space station requirements.

(3) Congress advocate the acquisition of additional orbiters—either private or public to support the space shuttle and space station mission requirements.

(4) Congress advocate the definition and development of an improved orbiter vehicle to support space shuttle and space station mission requirements.

(5) Congress continue the support of NASA's effort to improve their future engineering and scientific manpower position with respect to hiring recent graduates.

(6) Congress continue the support and funding of Unmanned Planetary Spacecraft.

UNITED TECHNOLOGIES PRATT & WHITNEY AIRCRAFT,
ENGINEERING DIVISION,
East Hartford Conn., April 18, 1984.

Hon. SLADE GORTON,
Chairman, Science, Technology and Space Subcommittee, Senate Commerce, Science, and Transportation Committee, Russell Senate Office Building, Washington, D.C.

DEAR CHAIRMAN GORTON: During the March 29th hearing by your Subcommittee on the fiscal year 1985 NASA Aeronautics budget, the question was raised as to which of the prop-fan concepts (i.e. single and/or counter-rotating prop-fans) should be pursued. A further question was asked as to when, if ever, these concepts should be flight tested. In his response to these questions, Mr. Krebs indicated that as a spokesman for industry he felt that there should not be any flight tests until further basic work was completed on all competing concepts.

Pratt & Whitney of United Technologies Corporation, the largest jet engine manufacturer in the free world, and a member of the Aerospace Industries Association for whom Mr. Krebs was testifying, takes strong exception to the position voiced by Mr. Krebs on this issue. We respectfully request that the attached Pratt & Whitney position paper on the NASA Prop-fan Program be included in the hearing record.

While we support full funding for the Prop-fan Program in the fiscal year 1985 budget, if it is not feasible to provide the entire $27 million shortfall, Pratt & Whitney urges this Committee to, as a minimum, provide the funds necessary to maintain the fiscal year 1987 flight test program reviewed and concurred with by the NASA Advisory Committee and enough additional monies to continue work on the other program elements described in the attached position paper, albeit on a stretched-out schedule.

Sincerely,

I. MENDELSON, *President.*

Enclosure.

PRATT & WHITNEY POSITION PAPER ON ADVANCED TURBOPROP—PROP-FAN PROGRAM—APRIL 18, 1984

This NASA Program which seeks to validate the concept of a high speed propeller has been highly endorsed by industry for several years. Delays caused by an inadequate budget in previous years have now put the program nearly two years behind schedule, in spite of the fact that program acceleration has been recommended by Industry and Congress for the last few years. NASA has indicated that approximately $41 million is necessary in fiscal year 1985 to keep all of the important program elements on schedule. Any reduction in this amount will result in further delays in this important program.

NASA has formulated a well planned, comprehensive technology and proof-of-concept program for the advanced turboprop system. The key element of this system is a new propeller design (prop-fan) which will enable future commercial and military transports to fly at the same speeds as today's transports while saving 15 to 35 percent in fuel costs. This new concept is currently scheduled for a 1987 flight demonstration which will verify the structural integrity and noise characteristics of this new high speed swept-bladed propeller. These tests will provide the proof-of-concept verification of the key technologies required for a competitive turboprop system. The funds to maintain the schedules for this test must be preserved in the fiscal year 1985 budget.

The remaining elements in this comprehensive NASA plan include turboprop engine technology programs which are essential to the success of the Prop-fan Program. They include performance evaluation of counter-rotating propeller models, advanced gearbox technology programs, and evaluation of candidate engine configurations. This plan represents a coordinated program, and all elements should be supported to the greatest extent possible in order that balance be maintained and all concepts which exhibit high payoff potential be evaluated.

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